

Russell L. Southern
Newton, Iowa

QUESTIONS AND ANSWERS

On the Practice and Theory of

STEAM and HOT WATER HEATING

Sixteenth Edition

BY R. M. STARBUCK

AUTHOR OF

Vols. I, II, III, and IV—"Questions and Answers on the
Practice and Theory of Sanitary Plumbing."

"Questions and Answers on the Practice and Theory of
Steam and Hot Water Heating."

"Estimating for the Plumbing Contractor."

"Modern Heating Illustrated."

"Plumber's Examination Outfit."

"Seven Hoover Code Drawings."

R. M. STARBUCK & SONS, INC.

HARTFORD, CONN.

1954

THE HISTORY AND LEGENDS

OF THE STATE OF NEW YORK

THE HISTORY AND LEGENDS OF THE STATE OF NEW YORK

Copyright, 1905, by R. M. Starbuck
Copyright, 1912, by R. M. Starbuck
Copyright, 1919, by R. M. Starbuck
Copyright, 1927, by R. M. Starbuck
Copyright, 1940, by R. M. Starbuck
Copyright, 1945, by R. M. Starbuck

BY R. M. STARBUCK

Author of

"The History and Legends of the State of New York"
"The History and Legends of the State of New York"
"The History and Legends of the State of New York"
"The History and Legends of the State of New York"
"The History and Legends of the State of New York"
"The History and Legends of the State of New York"
"The History and Legends of the State of New York"
"The History and Legends of the State of New York"

THE HISTORY AND LEGENDS

OF THE STATE OF NEW YORK

1905

PREFACE

THIS BOOK, popularly known as the Grey Book, is concerned with subjects pertaining to the heating of dwellings and other moderate sized buildings, rather than with large undertakings.

The book is especially valuable to those who are preparing for examinations. To afford additional help in such efforts, we are adding to this edition a list of 350 examination questions. With the exception of questions involving mathematics, all questions in this list are answered in this book. In seeking the answers to these questions, our advice is to make good use of the index. In many instances subjects are indexed under two headings.

None of the building trades has made greater advancement in recent years than the heating industry has. We have kept pace with this advancement by adding in the preceding revision, a liberal amount of information on the modern subjects of indirect hot water heaters and forced circulation hot water heating.

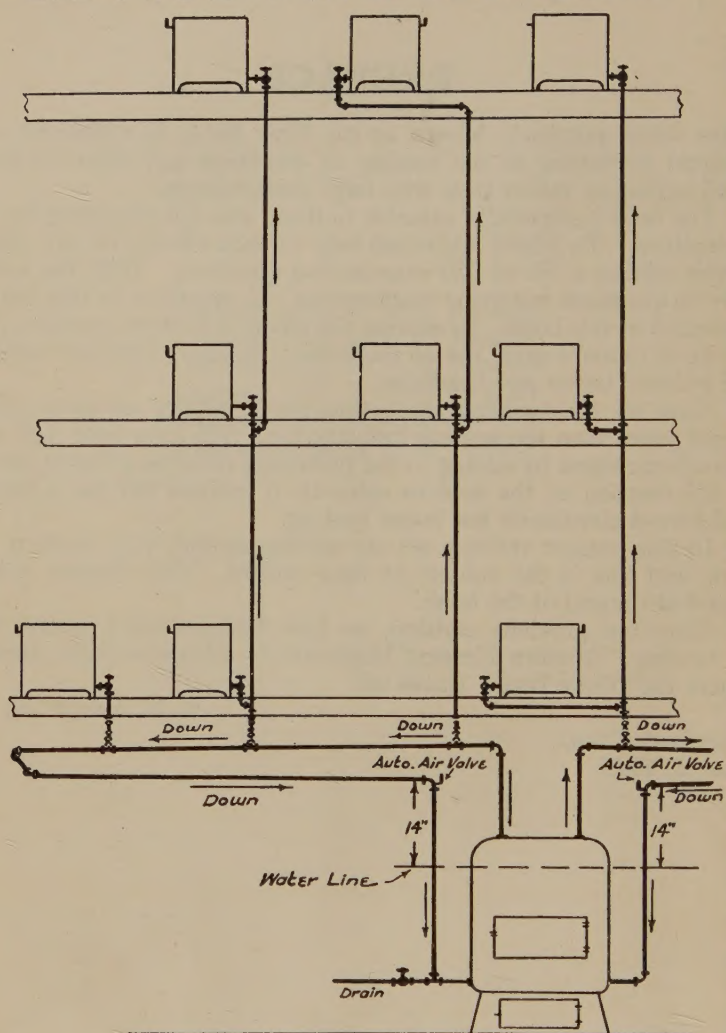
In this present revision we are adding another very modern feature, and this is the subject of heat control. This chapter will be found at the end of the book.

Since our previous revision, we have brought out a second book on heating, "Modern Heating Illustrated." This new book takes up where the "Grey Book" leaves off.

R. M. STARBUCK

Hartford, Conn.
June 5, 1945

ONE-PIPE SYSTEM OF STEAM HEATING



CHAPTER I

HEAT

What is heat?

According to what is known as the molecular theory, all bodies are made up of rapidly vibrating particles, the hottest bodies being those whose particles move or vibrate with the greatest rapidity, and through the greatest distances. Therefore the conclusion is reached that heat is not a substance, but a form of motion, and this condition may be transferred from one body to another. This theory explains perfectly and in a simple manner, the various actions of heat.

What are the general effects of heat?

When heated, the particles of a body tend to repel each other, and as a result of this action the body expands, and this expansion if carried far enough, finally produces a change in the state of the body, the point at which such change takes place varying with each different substance. As an example of this change of state, we know that a cake of ice when subjected to heat, melts and becomes water, and again, this water when subjected to further heat again changes its state and becomes steam.

In what ways may heat be transferred from one body to another?

In three ways, by conduction, by convection, and by radiation.

How is heat transferred from one body to another by conduction?

By the direct contact of the particles of a body with each other, or by the contact of one body with another. Thus a heated bar of iron will transmit heat to another bar when in contact with it.

How is heat transferred from one body to another by convection?

By means of water or other fluids, which convey it from one point to another.

How is heat transferred from one body to another by radiation?

Through such a medium as currents of air.

With which of these three methods of transmission of heat is steam and hot water heating mostly concerned?

With transmission by radiation. In heating by means of a stove or furnace, the heat is radiated or given off into the room, but in heating by steam or hot water, the heating of the room is accomplished by the circulation of the air in the room.

How is heat measured?

By the heat unit.

What is a heat unit?

A heat unit is a scale used in the measurement of the effect of heat. All heating operations are figured on the heat unit, and measured by it.

What measure of heat is in general use in this country?

This measure or unit is the British Thermal Unit, generally referred to as B. T. U.

Define the British Thermal Unit.

A B. T. U. is the amount of heat necessary to raise one pound of water from 32 to 33 degrees Fahrenheit. This amount never varies.

What is the Fahrenheit scale?

On the Fahrenheit scale, readings start at zero, positive readings being above, and negative readings below. On this scale the boiling point is at 212 degrees, and the freezing point at 32 degrees.

What other scale is there beside the Fahrenheit scale that is used to a considerable extent?

The Centigrade scale.

What is the Centigrade scale?

On the Centigrade scale or thermometer, the freezing point is marked 0 degrees, and the boiling point 100 degrees. The distance between these two points of chief importance is divided into 100 points, and the same gradation carried below the freezing point and above the boiling point.

How may Fahrenheit readings be converted into Centigrade readings?

This may be done by using the following formula:—Fahrenheit = $9/5C + 32$. According to the formula, if you desire to get Fahrenheit from a Centigrade reading, get $9/5$ of the Centigrade temperature, and add 32.

How may Centigrade readings be converted into Fahrenheit readings?

This may be done by using the following formula:—Centigrade = $5/9 (F-32)$. According to the formula, if a Centigrade reading is required from a Fahrenheit reading, subtract 32 degrees from the Fahrenheit, and multiply the result by $5/9$.

What is the mechanical equivalent of heat?

One unit of heat is capable of raising 772 pounds one foot high. This is called "foot pounds."

What is meant by evaporation or vaporization?

By either of these terms is meant the process of changing water or other liquids into vapor by the application of heat.

What is latent heat?

Latent heat is the heat expended in changing a body from the solid to the liquid state, or from the liquid to the gaseous state, without change of temperature.

What is meant by the temperature of fusion?

The temperature at which a body changes from a solid to a liquid state is called its temperature of fusion; and the number of B. T. U. required to effect this change in a body weighing 1 lb. is called its latent heat of fusion.

What is meant by the temperature of vaporization?

The temperature at which a body changes from a liquid state to a vapor (gas) is called its temperature of vaporization; and the heat required to effect this change in 1 lb. of the liquid is called its latent heat of vaporization.

What happens when the action of condensation or of freezing takes place?

When a vapor changes back to a liquid, it is said to condense; and when a liquid changes back to a solid, it is said to freeze; in either case, an amount of heat, equal to the latent heat of vaporization or of fusion, as the case may be, must be abstracted from (given up by) the body before the change can be effected.

What is meant by saturated steam?

When steam is in contact with the water from which it was originally generated, it is called saturated steam.

What is meant by superheated steam?

When steam is not in contact with water, it may be heated like any other gas, or like air, until it reaches a temperature higher than the boiling point. When so heated it is known as superheated steam.

What is meant by the equalization of heat between two bodies?

When two bodies having different temperatures are brought in contact with each other, the temperature of the two bodies will after a time become the same. The heat of the body having the higher temperature will be absorbed by the other until the temperature of the two is equalized. This is true whether the bodies are solid or liquid.

Give an illustration of the equalization of temperature between two bodies.

If a quantity of water at 100 degrees is poured into an equal quantity of water at 200 degrees, the temperature of the water will become 150 degrees.

The amount of heat contained in air.

When a current of heated air of a given number of cubic feet per minute is cooled, the amount of heat given off in the operation may be measured by the following rule:

Find the product of the given amount of air, the number of degrees of temperature through which it has been cooled, and the heat in 1 cubic foot of air at the original temperature, as found in the following table. Divide this product by the original temperature, and the quotient will give the number of heat units given off.

PROPERTIES OF AIR AT PRESSURE OF 14.7 LB. PER SQ. IN.

Tem- pera- ture. F.	Weight per Cubic Foot. Lb.	B. T. U. Given Up by 1 Cu. Ft. of Air in Cooling to 0°.	Tem- pera- ture. F.	Weight per Cubic Foot. Lb.	B. T. U. Given Up by 1 Cu. Ft. of Air in Cooling to 0°.
0	.08635	.0000	75	.07424	1.3225
2	.08597	.0408	80	.07355	1.3975
4	.08560	.0813	85	.07288	1.4713
6	.08523	.1214	90	.07222	1.5438
8	.08487	.1613	95	.07157	1.6149
10	.08451	.2007	100	.07093	1.6847
12	.08415	.2398	110	.06968	1.8205
14	.08380	.2786	120	.06848	1.9518
16	.08344	.3171	130	.06732	2.0786
18	.08309	.3552	140	.06620	2.2013
20	.08275	.3931	150	.06511	2.3196
24	.08206	.4678	160	.06406	2.4344
28	.08139	.5413	170	.06305	2.5458
32	.08073	.6136	180	.06206	2.6532
36	.08008	.6847	190	.06111	2.7577
40	.07944	.7547	200	.06018	2.8587
45	.07865	.8406	210	.05929	2.9572
50	.07788	.9249	220	.05841	3.0521
55	.07712	1.0074	230	.05756	3.1444
60	.07638	1.0885	240	.05674	3.2343
65	.07566	1.1681	250	.05594	3.3216
70	.07494	1.2459	260	.05517	3.4069

The following table will be found of value in heating calculations.

VOLUME, DENSITY, AND PRESSURE OF AIR
(*D. K. Clark*)

De- grees F.	Volume at Atmospheric Pressure		Density, lb. per cu. ft. at Atmos- pheric Pres- sure	Pressure at Con- stant Volume	
	Cubic Ft. in 1 lb.	Compara- tive Volume		Pounds per Sq. In.	Compara- tive Pres- sure
0	11.583	.881	.086331	12.96	.881
32	12.387	.943	.080728	13.86	.943
40	12.586	.958	.079439	14.08	.958
50	12.840	.977	.077884	14.36	.977
62	13.141	1.000	.076097	14.70	1.000
70	13.342	1.015	.074950	14.92	1.015
80	13.593	1.034	.073565	15.21	1.034
90	13.845	1.054	.072230	15.49	1.054
100	14.096	1.073	.070942	15.77	1.073
110	14.344	1.092	.069721	16.05	1.092
120	14.592	1.111	.068500	16.33	1.111
130	14.846	1.130	.067361	16.61	1.130
140	15.100	1.149	.066221	16.89	1.149
150	15.351	1.168	.065155	17.19	1.168
160	15.603	1.187	.064088	17.50	1.187
170	15.854	1.206	.063089	17.76	1.206
180	16.106	1.226	.062090	18.02	1.226
200	16.606	1.264	.060210	18.58	1.264
210	16.860	1.283	.059313	18.86	1.283
212	16.910	1.287	.059135	18.92	1.287
220	17.111	1.302	.058442	19.14	1.302

CHAPTER II

BOILERS FOR HEATING PURPOSES

Of what materials are boilers for heating purposes constructed?

Of cast iron, wrought iron and steel.

Which of these materials is now most generally used in the construction of boilers for heating purposes, and why is it preferable?

Cast iron has of late years been very largely adopted by manufacturers of heating boilers, owing chiefly to the fact that it is far less liable to rust than either wrought iron or steel. It is a well-known fact that the damage to a heater due to rust usually occurs during the summer months, when the apparatus is not in use, and often is the result of damp or wet cellars.

Why is cast iron less susceptible to rust than wrought iron or steel?

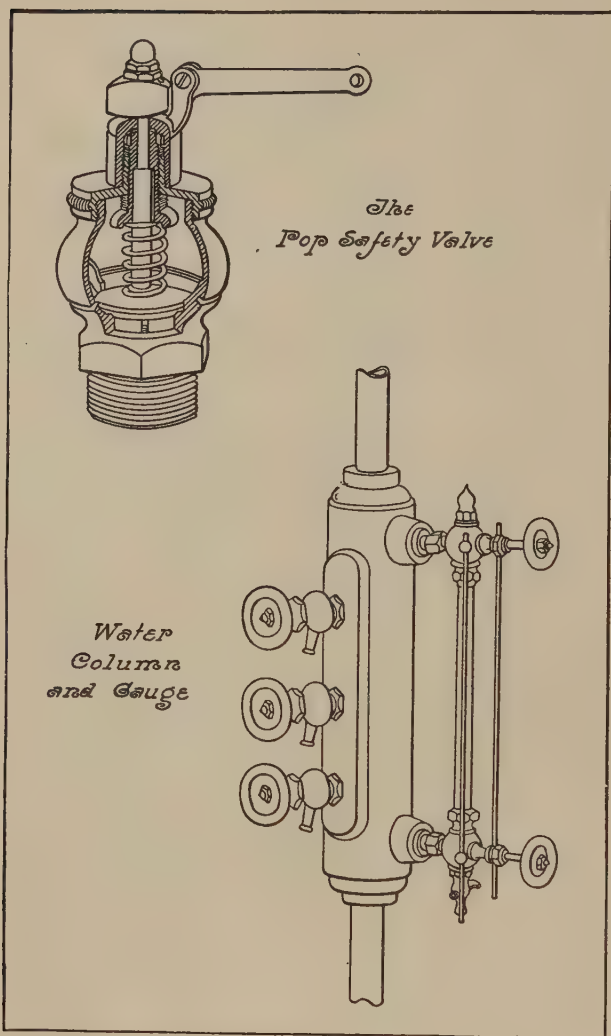
The finer iron is worked, the less porous it becomes, and consequently the greater will be its tendency to rust. As an example of this, if we breathe on a razor blade and lay it aside for a time, it will be found on examination to be rusted, while cast iron under like circumstances would not be effected in the least. A thin coating of rust will form over the surface of cast iron, which really acts as a protection to the iron, but when the casting is broken open, the fracture will be found bright and clean, showing that the rust had not penetrated beyond the surface. It is for these reasons that cast iron is now so generally used in the construction of heaters.

What is the length of life of a cast iron heater as compared with a wrought iron heater?

A cast iron heater has about twice the length of life of a wrought iron heater.

What is the comparative length of life of wrought iron and steel heaters?

The wrought iron heater has about four or five times the length of life that a steel heater has.



Water Column and Gauge—Pop Safety Valve

What styles of boilers are used for power purposes?

Either upright or horizontal tubular, or fire-box boilers are those generally in use for this purpose. A type of tubular boiler known as the water tube boiler has come into general use, and many claims as to its utility have been made by manufacturers of this style of boiler. In any tubular boiler much depends upon the character of its construction, and upon its proper setting.

How is the horsepower of a tubular boiler determined?

15 square feet of heating surface is estimated as one nominal horsepower.

What materials are necessary to properly set or brick in a standard type of horizontal tubular boiler?

The materials required in this work, and their proper amounts are given in the following table.

MATERIALS FOR BRICKWORK, REGULAR TUBULAR BOILERS

Boilers	No. Common Brick	No. Fire Brick	No. Bushels Sand	No. Barrels Cement	Pounds Fire Clay	No. Bbls. Lime
30 in.x 8 ft.	5200	320	42	5	192	2
30 in.x 10 ft.	5800	320	46	5½	192	2½
36 in.x 8 ft.	6200	480	50	6	288	2½
36 in.x 9 ft.	6600	480	53	6½	288	2¾
36 in.x 10 ft.	7000	480	56	7	288	3
36 in.x 12 ft.	7800	480	62	8	288	3¼
42 in.x 10 ft.	10000	720	80	10	432	4
42 in.x 12 ft.	10800	720	86	11	432	4¼
42 in.x 14 ft.	11600	720	92	11¾	432	4½
42 in.x 16 ft.	12400	720	99	12½	432	5
48 in.x 10 ft.	12500	980	100	12½	590	5¼
48 in.x 12 ft.	13200	980	108	13½	590	5½
48 in.x 14 ft.	14200	980	116	14½	590	5¾
48 in.x 16 ft.	15200	980	124	15½	590	6
54 in.x 12 ft.	13800	1150	108	13¾	690	5½
54 in.x 14 ft.	14900	1150	117	15	690	6
54 in.x 16 ft.	16000	1150	126	16	690	6¼
60 in.x 10 ft.	13500	1280	108	13½	768	5½
60 in.x 12 ft.	14800	1280	118	14¾	768	6
60 in.x 14 ft.	16100	1280	128	16	768	6½
60 in.x 16 ft.	17400	1280	140	17½	768	7
60 in.x 18 ft.	18700	1280	148	18¾	768	7½
66 in.x 16 ft.	19700	1400	157	19¾	840	8
72 in.x 16 ft.	20800	1550	166	20¾	930	8½

It is well to state that the above amounts allow a small percentage for necessary or unavoidable waste.

When wrought iron tubular or fire-box boilers are used for heating purposes, how are their capacities determined?

For each rated horsepower there is figured 100 square feet of direct radiation for steam, and 160 to 170 square feet of direct radiation for hot water, and the same allowance must be made for mains and risers and for other styles than direct radiating surface, as made when cast iron heaters are used.

What are the principal types of cast iron boilers generally used for heating purposes?

Round or sectional boilers are generally used for this purpose.

Describe the round boiler.

Round boilers are usually made up of a series of cylindrical parts or sections bolted or nipped together. In this boiler, the smoke and products of combustion pass into various spaces or flues, and upward through the boiler into the smoke pipe, which in this type is usually placed at or near the top, and at the rear of the upper section or cylinder. Boilers of this class are made in a variety of styles for both steam and hot water heating.

Describe the sectional boiler.

Sectional boilers as used for heating purposes may properly be divided into two classes, brick set or portable. This form of boiler is usually made up of a number of upright sections in the form of an inverted U, narrow legs or water ways being connected to a hollow base or header containing water, into which base return water from the heating system is conveyed. The upper part of the boiler or heating surface above the fire is usually divided into a series of openings or horizontal flues giving a passage for the smoke and products of combustion to the rear of the boiler. In some types of boilers of this class, the smoke and gases of combustion are carried two or three times across or through the length of the boiler. These boilers are spoken of as of the slab type of construction. Boilers of this class by means of the arrangement of the castings are built for either brick setting or portable setting. In the former case, with the exception of the front, the boiler is encased in brick and in the latter case, the outside surface of the casting, with the exception of the front, is covered with a plastic cement, usually a mixture of asbestos and magnesia. The smoke hood or bonnet for a boiler of this type is placed at the top end of the rear section, in the center of the boiler.

How are cast iron heating boilers rated?

The capacity or rating of cast iron boilers for heating purposes depends largely on the character of construction. Some

boilers are so constructed as to have a large amount of prime or direct heating surface in proportion to the amount of grate surface, and when so constructed as to utilize all heat and gases of combustion, they may be put down as much more efficient than those types of boilers which do not utilize all the products of fuel consumed. It is impossible to give accurate data on grate and heating surface as so much depends on the type or character of boilers, that no two types can be figured alike. It may be well to state that our readers will find this idea more clearly discussed under the subject of the requirements for a good boiler.

We give the following table as illustrative of the comparison of heating and grate surface, square inches of smoke flue, and square feet of radiation.

RELATIVE PROPORTIONS OF STEAM HEATING APPARATUS

Sq.Ft.of Heating Surface	Sq.Ft.of Grate Area	Sq. Ins. of Flue	Sq.Ft.of Radia- tion	Ratio of Surface to Contents		
				1:50	1:70	1:90
67	3.5	96	400	20,000	28,000	36,000
83	4	96	500	25,000	35,000	45,000
116	5.8	96	700	35,000	49,000	63,000
167	8.3	110	1000	50,000	70,000	90,000
250	12.5	150	1500	75,000	105,000	135,000
333	16.5	195	2000	100,000	140,000	180,000
416	15.5	248	2500	125,000	175,000	225,000
500	18.6	300	3000	150,000	210,000	270,000
584	21.6	348	3500	175,000	245,000	315,000
666	24.5	398	4000	200,000	280,000	360,000
750	27.5	445	4500	225,000	315,000	405,000
834	26	485	5000	250,000	350,000	450,000
916	28.5	530	5500	275,000	385,000	495,000
1000	31	575	6000	300,000	420,000	540,000
1250	38.5	715	7500	375,000	525,000	675,000
1333	41	760	8000	400,000	560,000	720,000
1500	45.5	860	9000	450,000	630,000	810,000
1666	50	955	10000	500,000	700,000	900,000

What is meant by the prime or direct heating surface of a boiler?

That part of the boiler is called prime or direct heating surface, which receives the direct action of the fire, or which receives direct radiant heat from the fuel.

What is meant by the indirect heating surface of a boiler?

That part of the surface, which receives convected or indirect heat from smoke and the gases of combustion is called indirect heating surface.

What are the requirements of a good boiler?

A good heating boiler is one made of good material, carefully constructed, and put together in such a manner as to be

free from leakage at its joints, when expansion due to heavy firing takes place. Boilers built in such a manner as to allow each each part of the boiler to expand under such conditions, are likely to be free from the possibility of the cracking of casting or sections.

It is conceded by the larger manufacturers of low pressure boilers that the nipple joint (either screw or push nipple), is the proper connection between castings or sections. Several years ago packed joints were largely used, that is, a packing was used between water openings, the sections being held together by bolts. Under conditions of possible heavy firing, or expansion due to rust, these joints gave way, and proved of considerable expense and annoyance. For this reason, this particular style of connection has been generally discarded. There should be no water connections or joints exposed to the direct action of the fire. The combustion chamber should be so constructed as to give room for the expanding gases and products of combustion, without choking, or deadening the action of the fire. The boiler should be so constructed as to produce a free, easy circulation within all its parts, and in the case of the steam boiler it should have a sufficient area of water surface to allow the disengagement of steam from the water without the possibility of the boiler foaming or priming.

Knowing the capacity of a boiler in square feet of radiation, how may the number of gallons of water the boiler is able to heat per hour be determined?

This depends upon the temperature to which the water is to be heated. Generally speaking, for house use, the square feet of capacity of boiler being given, add 33 1/3% to that amount, and the result will be the number of gallons that may be heated per hour.

Should a boiler be used to its full rated capacity?

It is economy to use a boiler of at least 25% greater capacity than that actually required by the amount of radiation called for. If coils are used instead of radiators, 50% should be added to the boiler capacity if it is to be run economically.

For direct-indirect work, about 25% should be added, and about 50% for indirect work.

How may the capacity of a boiler be determined?

To give a clear idea of the manner in which this calculation is made, we give the following as an example.

Suppose that a steam heating system is to supply the following amounts of radiation: 550 square feet direct radiation, 300 square feet indirect radiation, 275 square feet direct-indirect

radiation, 125 feet of 1-inch coil, 50 feet of 3-inch main, 150 feet of 1¼-inch risers, and 125 feet of 1-inch risers.

The equivalent in square feet of direct radiation of these several amounts would be the following:

550 square feet direct radiation.....	equals	550 sq. ft.
300 square feet indirect radiation.....	equals	450 sq. ft.
275 square feet direct-indirect radiation....	equals	344 sq. ft.
125 lineal feet 1-inch coil.....	equals	63 sq. ft.
60 lineal feet 3-inch main.....	equals	54 sq. ft.
150 lineal feet 1¼-inch risers.....	equals	65 sq. ft.
125 lineal feet 1-inch risers.....	equals	41 sq. ft.

Total..... 1567 sq. ft.

This system calls for 1567 square feet of direct radiation according to the above calculation, and would therefore require a boiler having a gross rating of 1600 feet.

What constitutes the trimmings of a steam boiler?

The safety valve, steam gauge, water column and try cocks, damper regulator, and draw-off cocks.

What is the purpose of the safety valve?

Its purpose is to relieve the pressure when it reaches a certain point, above which it would be dangerous to rise.

How is the safety valve regulated?

Usually by a lever on which there is a movable weight, which can be set at any pressure.

What style of safety valve is generally used on low pressure boilers?

Low pressure boilers are generally provided with "pop" or spring safety valves.

How should the safety valve be located?

It should be located on the top of the boiler or steam dome.

At what point should the safety valve be set on low pressure systems?

It should be set to blow off at a pressure not exceeding five to ten pounds.

What is the purpose of the steam gauge?

Its purpose is to indicate the pressure of steam within the boiler.

Where should the steam gauge be located and connected?

It should be connected direct to the steam space in the boiler, and be provided with a siphon.

What kind of steam gauge should be used on a low pressure heating plant?

One that will register up to 15 pounds.

What is the water column and gauge, and its purpose?

It is a hollow tube provided with a gauge glass, located at the side of the boiler, and connecting at top and bottom into the boiler. Its purpose is to show the height at which the water stands in the boiler.

What precautions are necessary in the care of the gauge glass and safety valve?

The gauge glass should always be kept clean, and the safety valve should be occasionally tested to make sure that it is not sticking to the valve seat.

How may the gauge glass be cleaned?

Remove the gauge glass and immerse it in a strong ammonia solution or in an acid which will remove grease from glass.

What is the damper regulator, and how does it work?

The damper regulator consists of a hollow vessel formed by two castings bolted together, with a rubber diaphragm between them, the lower casting being connected to the steam space of the boiler by means of a short nipple. Through an opening in the top of the upper casting a plunger works, and across this plunger and connected to an upright lip on the edge of the diaphragm casting is a rod, from the ends of which chains connect to the draft door and check damper door of the boiler.

As steam pressure rises, the pressure against the under side of the rubber diaphragm is transmitted to the plunger which is raised, thereby operating the rod or lever, and the chains connecting with the draft and check damper doors. The sliding weight usually on the rod, may be set so that the leverage may be smaller or greater according to the pressure of steam carried on the apparatus, before the operation of the doors will take place. By means of the damper regulator the rise and fall of temperature in the boiler may so regulate the draft that an even temperature may be obtained.

How should the damper regulator be adjusted?

The chains should be so set that the draft door and check

draft will each be closed when the regulator lever is level, and there is no steam in the boiler.

What is the purpose of the altitude gauge on a hot water heating system?

By the use of an altitude gauge at the boiler, the necessity of watching the expansion tank to know the amount of water in it, is avoided, as the gauge at the boiler registers the height of water in feet in the system.

Explain the action and method of adjusting the altitude gauge.

The gauge has two dials, the red one being moveable only by hand, the black one being connected with the mechanism of the gauge. When the system is first filled to the required height, the spring dial of the gauge shows the height in feet of the water in the system. The face of the gauge is then taken off, and the red dial moved to a point directly under the steam dial, and pointing to the same number on the gauge. As the water in the system evaporates by use, the spring dial drops away from the red dial, indicating less water in the system, and the operator may know that the water is low in the system, when he should refill it until the two dials are in exactly the same position.

At what pressure is a low pressure boiler most economically run?

At two pounds pressure or less.

What precaution should always be taken before starting the fire or putting on the draught in a steam boiler?

The water gauge should always be examined. Many boilers have been injured by neglecting this precaution.

What precaution should be taken when the water in the steam boiler is found to be low?

The fire should be banked with ashes, wet or dry, and the feed door opened. When the boiler has cooled sufficiently, it may be slowly filled.

What should be done after the boiler is first fired?

The fire should be drawn and the boiler blown off while under pressure.

How often should steam boilers be cleaned?

Every steam boiler should be cleaned and tested twice each year.

How may a boiler be cleaned?

Kerosene oil will clean a boiler, and remove the scale.

In starting a fire where should the water stand?

About midway of the water gauge.

Should the ash pit door be opened to secure a draft?

It should not, as the opening in the door should be sufficient to give the fire all the draft it needs.

What is a common reason for the water leaving a steam boiler and rushing up into the radiation?

A common reason is that when steam gets low, the person operating the boiler in his anxiety to get steam up quickly, opens all drafts and gets up a fire far heavier than the boiler requires, with the result that the water in the boiler boils so strongly that it forces itself out of the boiler and into the piping and radiation.

What is the cause of nervous or unsteady water lines in low pressure boilers?

This trouble often results from oil in the boiler, the oil usually being present by reason of its use in the construction of the piping and manufacture of the boiler and radiators. The oil rests on the surface of the water in the boiler, forming a sort of scum, and when this occurs, the bubbles of air formed by the boiling water cannot reach the surface of the water and burst off into steam. This causes a commotion, the bubbles seeking an outlet naturally finding it in the connection to the water column, or gathering in such force under a portion of the scum, that they break together, and with such force as to frequently force water into the steam main, often causing a vacuum which will empty the water glass and water column connections entirely. There are other causes for water leaving the gauge glass, due in some instances to the character of construction of the boiler, or to the manner of connecting the water column.

What is the remedy for nervous or unsteady water lines in low pressure boilers?

Blow the boiler off under pressure. This will usually remove most of the oil, if the unsteady line is due to oil. It may be necessary to repeat this operation several times, at intervals of a few days, before the boiler is entirely clean. If the cause be due to the construction of the heater, it may be necessary to use an equalizing pipe, that is, to make a direct connection from an opening in the top of the boiler to a return opening in the bottom of the boiler, or to change the piping or boiler connections in such a way as to prevent the siphonage of water into the steam mains.

CHAPTER III

THE CHIMNEY FLUE

What are the purposes of the chimney?

To carry off smoke and gases, and to create the draft necessary to burn the fuel.

How is draft produced?

It is impossible to create a draft in a chimney unless the upward velocity of the heated gases is sufficient to overcome the pressure of the atmosphere, which is 14.7 pounds per square inch at sea level. As the gases expand, they are forced upward by the heavier air which enters through the draft door in the heater. This action overcomes the pressure of the atmosphere, and results in what is called draft.

What height does a chimney need to produce a good draft?

Thirty-five or forty feet seem from experience to be the minimum height which a chimney should have to produce a satisfactory draft. Flues of less height often give fairly good results, but are not dependable.

Chimneys should always be carried at least two feet above the highest point of the roof. In the case of a low chimney, the wind will often travel over the roof and actually destroy the draft.

What is the effect of draft?

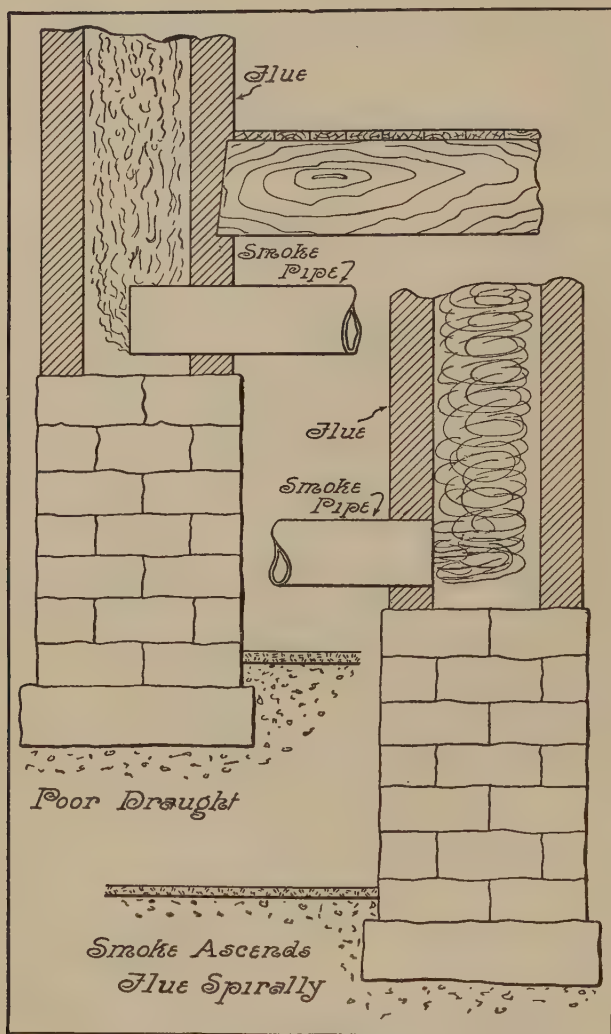
Its effect is to increase combustion.

What is required of a flue in order that it may produce good draft?

Height is an important factor, and also area, the latter being dependent on the size of the boiler.

Upon what does the amount of draft necessary for a boiler depend?

The two principal features upon which draft is dependent are the nature of the fuel used, and the construction of the boiler, that is, whether it has a direct draft or not.



Correct and Incorrect Smoke Pipe Connections

What factor determines the necessary size of flue?

The area of grate surface determines this matter.

How are flue linings rated?

Round flue linings, whether tile or fire clay, are rated according to their inside dimensions. Square or rectangular flue linings are rated by their outside dimensions.

In what way does the shape of the flue effect the work of the boiler?

Chimney flues are nearly always square, round or oblong. Round flues are most efficient, square flues next, and oblong flues least efficient.

Heated gases and smoke rise through a flue with a spiral motion, and because of that fact the round flue is most effective. Because of its corners and ends, the oblong flue has more dead air space, and is therefore less effective. The dead air spaces are not only of no aid to the draft, but because of the friction which they create, they are in reality destructive to draft.

Is a square flue better than a rectangular one?

It is, for in shape it is nearer like the circular flue.

How should a flue be finished inside?

It should be made as smooth as possible, in order to reduce the amount of friction, that the escaping smoke and gases may have the greatest possible velocity.

What are the advantages of tile-lined flues?

A tile-lined flue is efficient because it is smooth. A rough plaster flue causes a greater amount of friction and this reduces the capacity of the flue by reducing the velocity of the smoke and gases.

A tile-lined flue reduces fire risk to a minimum, and when supported on a firm foundation is to be considered the best kind of construction.

The lining for a flue should be well and carefully cemented, and the joints made as smooth as possible. All holes should be cemented, as they offer friction.

In what additional way may the draft of a chimney be increased?

By increasing the height of the chimney.

What are some of the common causes of poor draft?

The smoke pipe may extend so far into the chimney as to

cut down its effective area. The chimney may be stopped up. There may be other openings into it, which might tend to lessen its effectiveness. The chimney may be new and not thoroughly dry, or the entrance of air through crevices may interfere with the draft.

The chimney may not be high enough, or surrounding houses may be so high as to prevent a good draft.

How should division walls in chimneys having two flues be constructed?

Such division walls should be at least two bricks thick, and they should be firmly supported. Under other conditions trouble may result in the following way. Particularly in speculative construction, these double flue chimneys are built with only a single brick partition between the flues, one flue generally serving the heater, and the other a fireplace possibly. Settling of the chimney is very liable to crack the flue lining and the brick partition, and allow cold air from the fireplace flue to enter the other flue, thereby either partially or almost wholly destroying the draft. This is most likely to result in unlined flues, but even with a lining the danger is not overcome, for the lining also cracks and opens up.

What may be the result of too strong a draft?

A greater amount of fuel will be consumed than is necessary, creating so intense a heat that water may be forced up into the radiators, which action would result in water hammer, and an unsteady water line in the boiler.

How may this trouble be remedied?

By placing a damper in the smoke pipe.

Should the flue to which the heater is connected have any other openings?

Nothing but the heater should be connected into it.

CHIMNEY FLUE SIZES FOR GIVEN AMOUNTS OF DIRECT STEAM RADIATION

Square Feet of Steam Radiation	Diameter of Round Flue	Square or Rectangular Flue
250	8 inches	8 in. x 8 in.
300	8 inches	8 in. x 8 in.
400	8 inches	8 in. x 8 in.
500	10 inches	8 in. x 12 in.
600	10 inches	8 in. x 12 in.
700	10 inches	8 in. x 12 in.
800	12 inches	12 in. x 12 in.
900	12 inches	12 in. x 12 in.

1000	12 inches	12 in. x 12 in.
1200	12 inches	12 in. x 12 in.
1400	14 inches	12 in. x 16 in.
1600	14 inches	12 in. x 16 in.
1800	14 inches	12 in. x 16 in.
2000	14 inches	12 in. x 16 in.
2200	16 inches	16 in. x 16 in.
3000	16 inches	16 in. x 16 in.
3500	18 inches	16 in. x 20 in.
5000	18 inches	16 in. x 20 in.

Note—If chimneys above 12x16 inches are less than 50 feet in height one size larger should be used. In finding proper size, a proper amount should be added to direct radiation, if direct-indirect, or indirect radiation is used.

CHIMNEY FLUE SIZES FOR GIVEN AMOUNTS OF DIRECT HOT WATER RADIATION

Square Feet of Hot Water Radiation	Diameter of Round Flue	Square or Rectangular Flue
400	8 inches	8 in. x 8 in.
500	8 inches	8 in. x 8 in.
700	8 inches	8 in. x 8 in.
850	10 inches	8 in. x 12 in.
1000	10 inches	8 in. x 12 in.
1200	10 inches	8 in. x 12 in.
1350	12 inches	12 in. x 12 in.
1500	12 inches	12 in. x 12 in.
1700	12 inches	12 in. x 12 in.
2100	12 inches	12 in. x 12 in.
2400	14 inches	12 in. x 16 in.
2700	14 inches	12 in. x 16 in.
3000	14 inches	12 in. x 16 in.
3400	14 inches	12 in. x 16 in.
3700	16 inches	16 in. x 16 in.
5100	16 inches	16 in. x 16 in.
5900	18 inches	16 in. x 20 in.
8500	18 inches	16 in. x 20 in.

Note—If chimneys above 12x16 inches are less than 50 feet in height, one size larger should be used. In finding proper size, a proper amount should be added to direct radiation, if direct-indirect, or indirect radiation is used.

What should be the area of a chimney flue?

From one-seventh to one-tenth of the area of the grate.

How can increased draft be offset?

By using smaller coal and by increasing the depth of the fire.

What is the smallest size of flue that should be used?

Nothing smaller than 8x8 inches, or 8 inches in diameter should be used.

What are the necessary requirements of draft for different fuels?

Wood requires very little draft, while the smaller sizes of coal require a large amount of draft.

Why is this so?

When wood is burned, the air passing under and through the grate has little to impede its passage, and the entire air capacity of the grate is utilized. Large coal does not pack as closely as the smaller sizes, and therefore the larger the size, the greater will be the amount of air that can pass through the grate, and the smaller the coal, the less will be this amount.

CHIMNEY FLUES

Steam *Square Feet Rated Boiler Capacity	Water *Square Feet Rated Boiler Capacity	Height of Chimney in Feet					
		30	40	50	60	80	100
250	375	7.0	...	...	...	...	...
500	750	9.2	8.8	8.2	8.0	...	...
750	1,125	10.8	10.2	9.6	9.3	8.8	8.5
1,000	1,500	12.0	11.4	10.8	10.5	10.0	9.5
1,500	2,250	14.4	13.4	12.8	12.4	11.5	11.2
2,000	3,000	16.3	15.2	14.5	14.0	13.2	12.6
3,000	4,500	18.5	18.2	17.2	16.6	15.8	15.0
4,000	6,000	22.2	20.8	19.6	19.0	17.8	17.0
5,000	7,500	24.6	23.0	21.6	21.0	19.4	18.6
6,000	9,000	26.8	25.0	23.4	22.8	21.2	20.2
7,000	10,500	28.8	27.0	25.5	24.4	23.0	21.6
8,000	12,000	30.6	28.6	26.8	26.0	24.2	23.4
9,000	13,500	32.4	30.4	28.4	27.4	25.6	24.4
10,000	15,000	34.0	32.0	30.0	28.6	27.0	25.4

*Indirect radiation should be made equivalent to direct radiation by adding 50 per cent.

Name some of the requirements in the construction of brick chimneys.

In the making of brick chimneys which have no flue lining, the joints between the bricks should be pointed, and the sides should not be plastered, as the plastering will fall off, leaving rough sides.

It should be seen to that chimney tops are tight, for a chimney top with loose joints through which the wind may blow, will make a good draft impossible. In order to ensure good joints, nothing but cement should be used on that part of the chimney which is exposed to the weather. When common mortar is used, rain and gas fumes will act on the lime in the mortar, resulting in the loosening of the bricks.

Chimneys should be built straight up when possible, with-

out offsets. Offsets invariably collect soot, thereby reducing the effective area of the chimney. Inasmuch as a chimney flue is no larger than its smallest area, it needs to be full area throughout.

How should chimneys be located?

The proper location of chimneys is a matter of importance, much greater importance than is generally known.

As a general thing the chimney should be located on the north and west sides of the house. The reason for this is that experience shows that when in this position there will be less interference from adverse currents of air and from winds which blow across the roof than when in other locations.

Chimneys built wholly in the interior of a house will produce better results than when built on an outside wall. An inside chimney is kept warmer owing to its protected position than an outside chimney, and the gases are therefore kept hotter. An outside chimney flue should be lined, and moreover the chimney on the exposed side should be made at least two bricks thick.

CHAPTER IV

FUEL AND COMBUSTION

What is combustion?

Combustion is chemical action, accompanied by the generation of heat. When such action takes place slowly, as when iron oxidizes in the air, the heat produced is imperceptible, but when it takes place rapidly, as in the burning of wood, coal, etc., the heat becomes intense. In the burning of ordinary fuel, the carbon and hydrogen of the wood or coal, combine with oxygen of the air, and produce combustion, without which no material results may be obtained from the fuel.

What does combustion depend upon?

Upon the presence of oxygen, without which it cannot take place.

What amount of air is required for perfect combustion?

Theoretically about 12 pounds of air is necessary for the complete combustion of 1 pound of anthracite coal, but in actual practice probably 20 to 24 pounds is closer to the actual amount used. This difference is caused by the influence of clinker, ash, and condition of the bed of fuel.

How is combustion calculated?

By the number of pounds of fuel consumed per hour by one square foot of grate surface.

What is an average amount of coal consumption?

One square foot of grate will consume about 5 pounds of hard coal per hour, or about 10 pounds of soft coal, under a natural draft. Under a forced draft, these amounts will be doubled.

What is the rate of evaporation in heating?

For $7\frac{1}{2}$ to 11 pounds of coal consumed, one cubic foot of water will be evaporated.

What is a good depth of fire?

A depth of twelve inches will do more efficient work than a less depth.

Why is the use of large sizes of coal usually inadvisable?

The use of large coal is attended with large air spaces between the pieces, and this large amount of air is too great for the gases escaping from the combustion of the coal, allowing the gases to escape into the chimney flue unburned.

Why is the use of the smallest sizes of coal inadvisable?

It packs down so compactly as to prevent the admission of the proper amount of air through the grate to produce good combustion.

Why is hard coal generally used for heating?

Because hard or anthracite coal burns more slowly, thereby lasting longer than soft coal. Moreover, it is cleaner to handle.

Why do fires burn best in cold weather?

Fires burn best in cold weather when it is clear, because under conditions which then prevail the pressure of the atmosphere is less on the air in the flue than under other conditions, resulting in greater velocity of the draft.

In rainy weather when the air is very heavy, the temperature of the gases which enter the flue must be increased beyond common requirements.

How may a fire be kept during mild weather?

A layer of ashes or fine siftings spread to a depth of a couple of inches over the surface of the fire will keep it sufficiently banked to hold it for hours without attention.

What is the proper manner of checking a fire?

This is properly done by closing the draft door which admits air under the grate, and by closing the damper in the chimney. The fire can be still further checked by opening the check damper in the smoke-hood at the top of the boiler. Checking by opening the firing door is wrong, for this will cause cold air to pass in and chill the water in the boiler.

How should the boiler be fired for best results?

A good clean fire should be maintained. The coal should not be packed tightly, and the fire should be kept clear of clinkers and of ashes. It may be stated that clinkers will not form to such an extent under slow and regular combustion as under reverse conditions.

How often should coal be put onto a fire?

Once in about eight hours during extreme cold weather,

once in twelve hours in moderatelyⁿ cold weather, and once in twenty-four hours during mild weather.

Grades of Coal Used in Heating;

Coal is divided into four general classes, as follows:—

1.—Anthracite coal, which contains from 92.31 to 100 per cent of fixed carbon and from 0 to 7.69 per cent of volatile hydrocarbons.

2.—Semi-anthracite coal, which contains from 87.5 to 92.31 per cent of fixed carbon and from 7.69 to 12.5 per cent of volatile hydrocarbons.

3.—Semi-bituminous coal, which contains from 75 to 87.5 per cent of fixed carbon, and from 12.5 to 25 per cent of volatile hydrocarbons.

4.—Bituminous coal, which contains from 0 to 75 per cent of fixed carbon and from 25 to 100 per cent of volatile hydrocarbons.

What are the common grades of anthracite coal?

Anthracite coal is rated according to the size of the lumps.

The grades together with the size of screen through which the coal will pass, are as follows:—

Buckwheat,—passes over $\frac{3}{8}$ in. mesh and through $\frac{1}{2}$ in. square mesh.

Pea,—passes over $\frac{1}{2}$ in. mesh and through $\frac{3}{4}$ in. square mesh.

Chestnut,—passes over $\frac{3}{4}$ in. mesh and through $1\frac{3}{8}$ in. square mesh.

Stove,—passes over $1\frac{3}{8}$ in. mesh and through 2 in. square mesh.

Egg, passes over 2 in. mesh and through $2\frac{3}{4}$ in. square mesh.

What are the common grades of semi-anthracite coal?

Semi-anthracite coal is sold in the same sizes and under the same commercial names as anthracite.

What are the common grades of bituminous coal?

Bituminous coal is divided in a general way into three grades, as follows:—

1.—Caking coal,—This coal is coal that when burned swells and fuses together and forms a spongy mass which extends over the entire grate. Caking coal is not easy to burn, as it is difficult to get air to pass through it, making it necessary frequently to break up the mass in order to produce proper combustion.

2.—Free-burning coal,—This coal is quite different from caking coal, inasmuch as it does not fuse when it is burned.

3.—Cannel coal,—This coal contains much hydrocarbon.

This makes cannel coal of value in making gas. It is not very generally used for generating steam.

What are the common sizes of bituminous coal?

Lump coal, which must pass over screen bars $1\frac{1}{2}$ inches apart.

Nut coal, which passes over bars $\frac{3}{4}$ in. apart, and through bars $1\frac{1}{2}$ inches apart.

Pea coal, which passes over bars $\frac{3}{8}$ in. apart, and through bars $\frac{3}{4}$ in. apart.

Slack coal, which includes all coal passing through bars $\frac{3}{8}$ in. apart.

What is the heating value of fuels?

A fuel's heating value is generally measured by the number of British Thermal Units given out in the full combustion of one pound of it.

What are average heating values, per pound of the most common fuels?

These values are approximately as follows:—

Anthracite coal	13,500 B.T.U.
Bituminous coal	14,000 B.T.U.
Wood	7,400 B.T.U.

M. Pouillet's Table
of
APPROXIMATE TEMPERATURE
OF FIRE

(Judged by Appearance of Fire.)

<i>Appearance of Fire.</i>	<i>Temperature.</i>
Red, Just Visible.....	977 deg. Fahr.
Red, Dull.....	1290 “
Red, Cherry Dull.....	1470 “
Red, Cherry Full.....	1650 “
Red, Cherry Clear.....	1830 “
Orange, Deep.....	2010 “
Orange, Clear.....	2190 “
White Heat.....	2370 “
White, Bright.....	2550 “
White, Dazzling.....	2730 “

CHAPTER V

RADIATION

What different types of radiation are commonly in use?

Steam and hot water heating is of three kinds, direct, indirect, and direct-indirect radiation.

What are the different types of radiators commonly used in steam and hot water heating?

Cast iron radiators and radiators made of wrought iron tubes with a cast iron base, are the common types, each of which may be arranged as direct, indirect, or direct-indirect radiation.

Where should direct radiation usually be located?

It should be located on exposed sides of rooms, or under windows.

Why should direct radiation be located in this way?

In order to cover the exposure and temper the cold air as it enters the room.

If radiators are placed on unexposed sides of rooms, what will be the result?

The cold air will be drawn across the room to the radiator so located, creating currents of air across the floor.

How is radiation sometimes located in large rooms?

Instead of placing all of it at one point, it is well to divide it into two or more radiators, according to the size of the room. As heating with steam or hot water is accomplished by the turning or circulation of the air in the room, it is well to divide and place the radiation at the most exposed points, in order to better heat the room.

How is radiation distributed in the heating of halls?

In small houses, such as the ordinary residence, a radiator placed in the lower hall if sufficiently large, will heat the hall above, but in large buildings, apartment blocks, etc., where the

hall space is large, the upper halls should have some radiation placed in them.

Is piping considered as radiation?

In reckoning boiler capacity, the piping is considered as radiation unless covered.

What radiation will one horsepower carry?

About 100 square feet of steam radiation or 160 to 170 square feet of hot water radiation.

How many kinds of radiating surface are there?

There are two kinds, prime radiating surface and extended radiating surface.

What is prime radiating surface?

Prime radiating surface is that surface against which the steam strikes, or hot water circulates.

What is extended radiating surface?

Extended radiating surface is the solid parts of the radiator which extend out from it, and against which water or steam does not strike.

How is the radiating surface of a radiator computed?

The radiating surface of a radiator in square feet, is the number of square feet of flattened surface of iron forming the radiator or radiator loop. The surface thus reckoned is prime radiating surface.

Is prime surface or extended surface most valuable in heating?

Prime surface is most valuable as this is the only surface which receives the direct action of the steam or hot water.

RADIATING SURFACE OF WROUGHT IRON PIPE

36 inches of 1	inch Pipe, equals 1 square foot of Surface
28 inches of 1½	inch Pipe, equals 1 square foot of Surface
24 inches of 1½	inch Pipe, equals 1 square foot of Surface
20 inches of 2	inch Pipe, equals 1 square foot of Surface
16 inches of 2½	inch Pipe, equals 1 square foot of Surface
13 inches of 3	inch Pipe, equals 1 square foot of Surface
12 inches of 3½	inch Pipe, equals 1 square foot of Surface
11 inches of 4	inch Pipe, equals 1 square foot of Surface
10 inches of 4½	inch Pipe, equals 1 square foot of Surface
9 inches of 5	inch Pipe, equals 1 square foot of Surface
8 inches of 6	inch Pipe, equals 1 square foot of Surface
7 inches of 7	inch Pipe, equals 1 square foot of Surface
6 inches of 8	inch Pipe, equals 1 square foot of Surface

SQUARE FEET OF RADIATION PER FOOT OF PIPE

Size of Pipe	Square Feet of Radiation	Size of Pipe	Square Feet of Radiation
$\frac{1}{2}$ inches	.22	3 inches	.916
$\frac{3}{4}$ inches	.275	$3\frac{1}{2}$ inches	1.055
1 inches	.346	4 inches	1.175
$1\frac{1}{4}$ inches	.434	$4\frac{1}{2}$ inches	1.309
$1\frac{1}{2}$ inches	.494	5 inches	1.455
2 inches	.622	6 inches	1.739
$2\frac{1}{2}$ inches	.753	7 inches	1.996
		8 inches	2.257

DIRECT STEAM RADIATING SURFACE DIFFERENT PIPES
WILL SUPPLY

Flow	Return	Square Feet of Direct Radiation
$1\frac{1}{4}$ inches	1 inches	175
$1\frac{1}{2}$ inches	$1\frac{1}{4}$ inches	250
2 inches	$1\frac{1}{2}$ inches	350
$2\frac{1}{2}$ inches	$1\frac{3}{4}$ inches	500
3 inches	2 inches	800
$3\frac{1}{2}$ inches	2 inches	1200
4 inches	$2\frac{1}{2}$ inches	1600
$4\frac{1}{2}$ inches	$2\frac{3}{4}$ inches	2000
5 inches	3 inches	2500
6 inches	3 inches	3600

SIZES OF ONE-PIPE STEAM MAINS

Size of Main	Square Feet Direct Radiation Supplied
2 inches	200 to 300
$2\frac{1}{2}$ inches	300 to 450
3 inches	450 to 700
$3\frac{1}{2}$ inches	700 to 1000
4 inches	1000 to 1300
$4\frac{1}{2}$ inches	1300 to 1600
5 inches	1600 to 2000

SIZES OF HOT WATER MAINS

Size of Main	Square Feet Direct Radiation Supplied
$1\frac{1}{2}$ inches	175
2 inches	300
$2\frac{1}{2}$ inches	400
3 inches	650
$3\frac{1}{2}$ inches	900
4 inches	1200
$4\frac{1}{2}$ inches	1500
5 inches	2000
6 inches	2700
7 inches	4000
8 inches	5500

TAPPING OF DIRECT HOT WATER RADIATORS

40 feet and less.....	1	inch x 1	inch
40 to 72 feet.....	1¼	inch x 1¼	inch
72 to 100 feet.....	1½	inch x 1½	inch
Larger than 100 feet.....	2	inch x 2	inch

TAPPING OF DIRECT HOT WATER RADIATORS.
TWO PIPE — TWO TAPPINGS

20 feet and less.....	¾	inch x ¾	inch
20 to 40 feet.....	1	inch x 1	inch
40 to 80 feet.....	1¼	inch x 1	inch
Larger than 80 feet.....	1½	inch x 1¼	inch

TAPPING OF DIRECT HOT WATER RADIATORS
ONE PIPE — ONE TAPPING

20 feet and less.....	1	inch
20 to 60 feet.....	1¼	inch
60 to 100 feet.....	1½	inch
Larger than 100 feet.....	2	inch

Upon what does the amount of radiation necessary to heat a building depend?

It depends upon the cubic contents of the space to be heated, the wall exposure, the glass exposure, and upon the construction, location and exposure of the building.

What is meant by exposed wall surface?

The entire outside wall surface of the room to be heated.

In figuring radiation for a building what information is necessary?

Radiation is estimated separately for each room to be heated. Therefore we must first know the dimensions of the room, and number and size of outside doors and windows.

With this data, first find the contents of the room to be heated, in cubic feet, by multiplying the length, width and height together. Next find the number of square feet of exposed wall surface, and the number of square feet of glass surface in windows and outside doors, treating the latter as if they were windows, and measuring the entire opening of each.

What method is used in estimating the radiation necessary to properly heat a room?

A very successful method is the following: Allow 1 square foot of radiation for each 200 cubic feet of space in the room to be heated, 1 square foot of radiation to each 20 square feet of exposed wall surface in the room, and 1 square foot for each 2 square feet of glass in the windows and doors of the room.

This method will give the amount of radiation for steam, and to it 60% should be added for hot water radiation.

As an illustration of the above rule, we will estimate the radiation necessary for a room 10x12 feet, with 10 foot ceiling, in which there is an exposed wall surface of 100 square feet, and glass surface of 50 square feet.

The cubic contents of the room will be $10 \times 12 \times 10 = 1200$ cubic feet.

For cubic contents of room allow 1 to 200	= 6 square feet
For exposed wall surface allow....1 to 20	= 5 square feet
For glass surface allow.....1 to 2	= 25 square feet

Total direct steam radiation necessary..... 36 square feet

Adding 60% to the above amount gives 58 square feet of direct hot water radiation for this room.

In dividing the radiation when figured according to the above method, it is well to take one loop from radiators on the south or warm side of the house, and add the same to each radiator on the north or cold side of the house.

What may be said in general concerning the estimating of radiation?

While the rule just given is an accurate method of finding the amount of radiation required, no rule can be given to cover all conditions, and the use of good judgment is always necessary. For instance, one house may be well protected, while another may be exposed, and allowance must be made for all these conditions.

What is the general requirement on which the above rule is based?

The rule is based on the customary requirement that at zero outside temperature, the temperature of all rooms heated shall be kept at 70°.

How is an approximate estimate of radiation sometimes made?

In using this table, the cubical contents divided by the number given, give the radiation required.

With an approved type of cast iron radiator, and working under the usual conditions, that is, with steam at 2 pounds, and 150° of difference between the temperature of the steam and the surrounding air, one square foot of direct steam radiation will heat approximately:

In a living room which has a large amount of glass, 2 or 3 exposures..	40
In a bath-room under the same conditions as the foregoing.....	40

In a living room with a large glass surface, and 1 or 2 exposures.....	50
In a living room with fair amount of glass, and one exposure.....	60
In sleeping rooms.....	55 to 70
In halls.....	50 to 70
In school rooms.....	60 to 80
In churches, halls, and places of large dimension and high ceilings	65 to 100
In factories, etc.....	75 to 150

The above is for direct steam radiation, and if direct-indirect radiation is used, 25% should be added, and 50% if indirect radiation is used.

For hot water work about 33 1/3% should be added to steam.

While the above is a fair estimate in very cold climates or for very windy and exposed positions, it would be well to modify it in figuring radiation for warmer climates.

SQUARE FEET OF EXPOSED GLASS SURFACE IN WINDOWS OF VARIOUS SIZES

Width of Window Feet	Height of Window in Feet															
	2	2½	3	3½	4	4½	5	5½	6	6½	7	7½	8			
1½	3	4	4½	5½	6	7	7½	8½	9	10	10½	11½	12			
2	4	5	6	7	8	9	10	11	12	13	14	15	16			
2½	5	6½	7½	9	10	11½	12½	14	15	16½	17½	19	20			
3	6	7½	9	10½	12	13½	15	16½	18	19½	21	22½	24			
3½	7	9	10½	12½	14	16	17½	19½	21	23	24½	26½	28			
4	8	10	12	14	16	18	20	22	24	26	28	30	32			
4½	9	11½	13½	16	18	20½	22½	25	27	29½	31½	34	36			
5	10	12½	15	17½	20	22½	25	27½	30	32½	35	37½	40			
5½	11	14	16½	19½	22	25	27½	30½	33	36	38½	41½	44			
6	12	15	18	21	24	27	30	33	36	39	42	45	48			
6½	13	16½	19½	23	26	29½	32½	36	39	42½	45½	49	52			
7	14	17½	21	24½	28	31½	35	38½	42	45½	49	52½	56			
7½	15	19	22½	26½	30	34	37½	41½	45	49	52½	56½	60			
8	16	20	24	28	32	36	40	44	48	52	56	60	64			

HEAT LOSS FROM WINDOWS AND OTHER BUILDING UNITS (E. R. Pierce)

Showing probable loss per square foot of surface of window per hour, with air at zero outside, 70 degrees F. inside. Normal or average wind velocity of 12 miles per hour.

Description of Window	Average Wind Velocity per Hour	Probable Loss per Sq. Ft. per Hour
Single thickness, common.....	12 miles	76.3
Double window	12 miles	35.7
Single skylight	12 miles	85.4
Double skylight	12 miles	38.5
Single monitor	12 miles	70.00

Loss of heat in B. t. u. from window surface per square foot per hour, for each degree of difference between temperature of rooms, and temperature of outside air, varying velocities of wind. Room not over 12 feet high. Heat to be continuous day and night.

Description of Glass	Wind Velocities per Hour		
	No Wind	Wind 2 Miles	Wind 5 Miles
Single thick common.....	.97	.99	1.02
Double window	.45	.46	.47
Single skylight	1.09	1.11	1.14
Double skylight	.49	.50	.51

Wind Velocities per Hour			
Wind 10 Miles	Av. Winter Wind 12½ Miles	Wind 15 Miles	Wind 20 Miles
1.07	1.09	1.17	1.26
.50	.51	.54	.58
1.20	1.22	1.30	1.41
.54	.55	.59	.63

If with an average wind of 12 miles per hour one square foot of window loses 1.09 B. t. u. per degree of difference, then at 70 degrees difference the loss will be $1.09 \times 70 = 76.30$ per hour and 100 square feet would lose $76.30 \times 100 = 7630$ B. t. u. per hour.

What part of the hot water radiation tends to heat best?

That on the upper floors.

Why is this true?

For the reason that hot water tends to flow to the highest point.

What part of the radiation should have the preference in size and arrangement of pipe connections?

That on the first floor.

Why should the first floor radiation have the preference?

For the reason that, owing to the tendency of hot water to

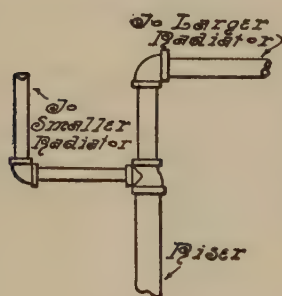


Fig. 1—To Feed Two Second Floor Radiators, One larger than the Other

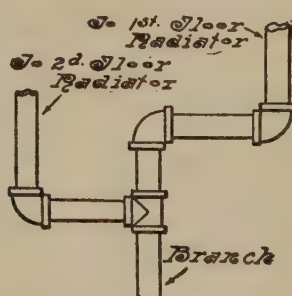


Fig. 2—To Feed Radiators on First and Second Floors from the Same Branch

rise quickly to the highest point of the system, the upper radiators on the system are liable to rob those on the lower floors of their share of the circulation or heat, and for this reason the radiators on the lower floor should be given the preference in the matter of connections.

How is preference given to radiator connections?

By increasing the size of connection to the radiator, and by taking it from the main or supply branch ahead of other radiators supplied by the same pipe. Any choking or retarding of the circulation should be done at the branch connection, as shown in the following illustrations which show some of the customary methods of favoring certain parts of the radiation.

CHAPTER VI

RADIATOR CONNECTIONS

How may hot water radiator connections sometimes be made if there is difficulty in running the flow pipe to the radiator in the ordinary manner?

The flow may be connected at the top of one end, and the return connection made at the bottom of the opposite end.

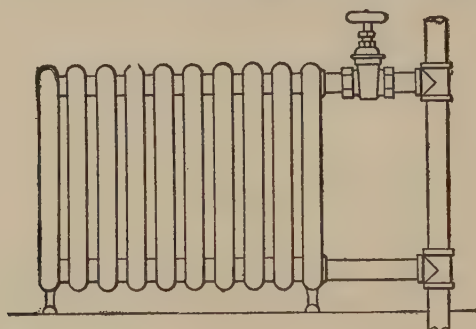


Fig. 3—Connections for Radiator on Over-head System

How may radiator connections be made on the overhead system?

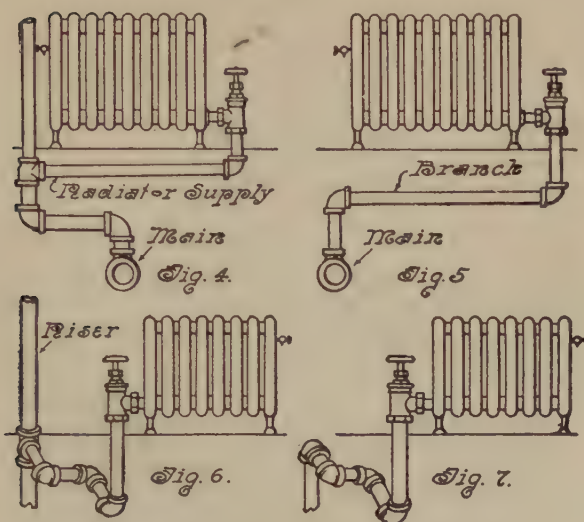
When the overhead system is used, the radiators may be fed at the top of one end, and the return taken out of the bottom of the same or opposite end, as occasion may require. The circulation of water in either case is positive. This connection is shown by Fig. 3.

How may radiator connections be made on the two-pipe steam system?

When this system is used, the flow connection may also be made at the top of one end of the radiator, and the return from the bottom of the opposite end. This method of connection is usually necessary when the piping is for the overhead system.

In general how should steam radiator connections be made?

They should be made in such a manner as to allow for expansion and contraction in the branch supply to the radiator.



Figs. 4, 5, 6, 7—Radiator Connections Allowing for Expansion and Contraction

This provision is shown in the following illustrations of radiator connectons.

Is there any advantage derived from the use of coils?

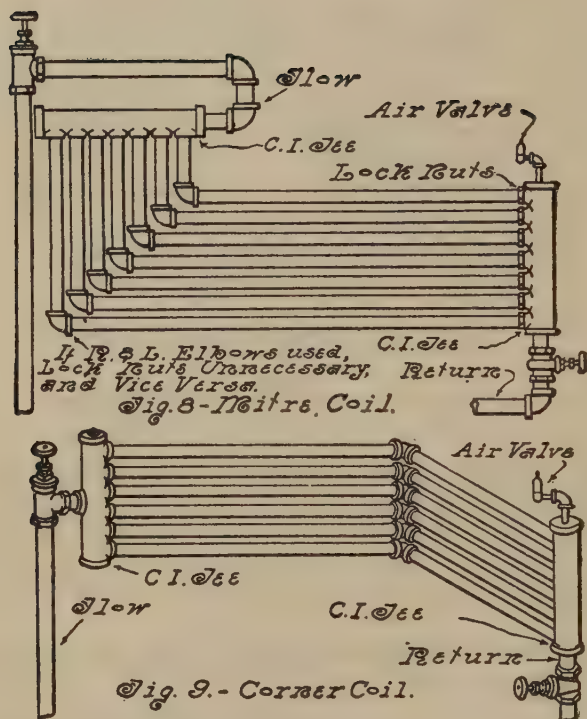
Considering the present low cost of cast iron radiation, and the cost of labor in the construction of coils, there is no advantage to be gained from the use of coils, as far as economy is concerned. In factories, where space cannot be given to radiators, wall coils may be used to advantage.

Should extra boiler power be added when coils are used?

About 20% should be added for all coils.

Why does the use of coils demand greater boiler power?

For the reason that coils condense steam or cool water about 20% faster than cast iron radiation.



Figs. 8 and 9—Coils

CHAPTER VII

INDIRECT RADIATION

Describe the indirect system of heating.

Instead of locating radiators in the rooms to be heated on the first or second floor, as in the direct system of heating, the radiators are located in the cellar or basement, usually directly under the rooms to be heated. There is placed in the floor of the room to be heated, or in the side wall above the baseboard, a register, and connection is made between this register and the radiator in the basement by means of tin or sheet iron pipe, for conveying the heated air into the room.

The indirect radiator is placed in a chamber into which fresh air is conveyed from outside, and to which the hot air flue to the register is connected.

How is the indirect radiator formed?

It is formed of any number of sections, bolted or nipped together, and is called an indirect stack.

What type of indirect radiator is now mostly used?

The cast iron radiator.

How should the indirect stack be located in its casing?

Never less than 14 inches above the water line of the boiler, with the top of the radiator not less than 10 inches below the top of the casing, and the bottom of the radiator not less than eight inches above the bottom of the casing.

How is the chamber for the indirect stack usually constructed?

Of galvanized iron, or of wood lined with tin, the former being preferable, as it presents a neater appearance and occupies less space.

How should the cold air duct be connected into the indirect stack?

It is best to connect it at the bottom of the chamber, but if impossible, at the end furthest from the register.

What should be the size of the cold air flue?

About $1\frac{1}{2}$ to 2 square inches of area for each square foot of radiation in the stack for the first floor; from 1 to $1\frac{1}{2}$ square inches of area for the second floor; and $\frac{3}{4}$ to 1 square inch of area for the third floor. The cold air flue should be about 75% of the area of the hot air pipes.

How is the size of the hot air flue from the stack calculated?

For each square foot of radiation in the stack, 2 square inches of area for hot water heating, and $1\frac{1}{2}$ square inches for steam heating.

Upon what are the sizes of hot air flues based?

The velocity of the air to the first floor is figured at $1\frac{1}{2}$ feet per second, to the second floor at $2\frac{1}{2}$ feet per second, and to the third floor at 5 feet per second.

What should be the sizes of registers used in indirect heating?

Effective register area should be 25% greater than that of the hot air flue serving it. These registers are of the same kind as those used in hot air heating.

How many floors should an indirect stack serve?

An indirect stack should serve one floor only, unless the boxing or casing is carefully subdivided.

How should returns be connected on indirect steam work?

They should always be connected into the main return, below the water line of the boiler.

Why should the return connection be made in this way?

In order to prevent the short circuiting of steam and the possible cutting off or holding back of return water from some other portion of the system.

What are the advantages and disadvantages of the indirect system?

The indirect system is more expensive to install than the direct system, but is considered the most healthful form of heating, as it is accompanied by a system of ventilation.

What is the rule for estimating indirect radiation?

Estimate the direct radiation necessary for the work in question according to the rule for figuring direct radiation, and for

indirect radiation add 50% to this amount for steam, and 75% for hot water heating.

Why is it necessary to provide more radiation for indirect work than for direct?

With direct radiation the air of the room is being constantly circulated. The air coming in contact with the radiator is warmed or tempered, the direct radiator accomplishing the work by heating or expanding the air sufficiently to cause an upward current, and consequently turning the air in the room. With the indirect radiator this is not so, as a sufficient quantity of cold air must be continually warmed and thrown into the room to change the temperature of the room to the required degree.

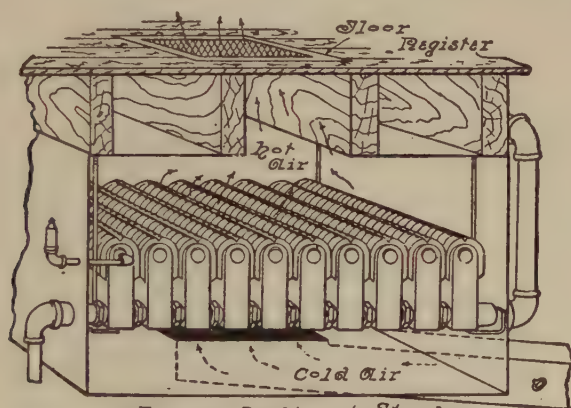


Fig. 10.- Indirect Stack

INDIRECT STEAM RADIATING SURFACE DIFFERENT PIPES WILL SUPPLY

Flow	Return	Square Feet of Indirect Radiation Supplied
1¼ inches	1 inches	100
1½ inches	1¼ inches	160
2 inches	1¼ inches	225
2½ inches	1½ inches	300
3 inches	2 inches	500
3½ inches	2 inches	750
4 inches	2½ inches	1000
4½ inches	2½ inches	1200
5 inches	3 inches	1600
6 inches	3 inches	2200

INDIRECT HOT WATER RADIATING SURFACE DIFFERENT
PIPES WILL SUPPLY

Size of Main	Square Feet Indirect Radiation
1½ inches	125
2 inches	200
2½ inches	275
3 inches	400
3½ inches	600
4 inches	800
4½ inches	1000
5 inches	1300
6 inches	1800
7 inches	2500
8 inches	3500

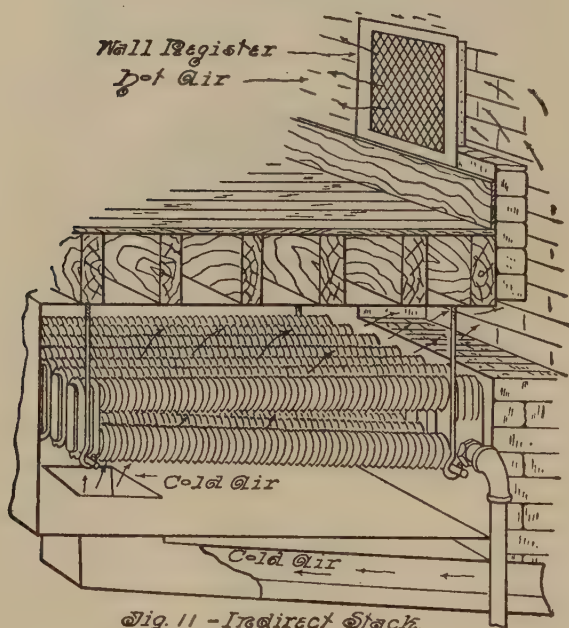


Fig. 11 - Indirect Hot Air.

FLUE SIZES FOR INDIRECT HOT WATER HEATING

Heating Surface	Area of Cold Air Duct	Area of Hot Air Flue	Size of Register
26 sq. ft.	36 sq. in.	48 sq. in.	8 x 12 inches
52 sq. ft.	54 sq. in.	72 sq. in.	9 x 12 inches
78 sq. ft.	72 sq. in.	96 sq. in.	10 x 14 inches
104 sq. ft.	90 sq. in.	120 sq. in.	12 x 15 inches
130 sq. ft.	108 sq. in.	144 sq. in.	12 x 19 inches
156 sq. ft.	126 sq. in.	168 sq. in.	14 x 22 inches
182 sq. ft.	144 sq. in.	192 sq. in.	14 x 24 inches
208 sq. ft.	162 sq. in.	216 sq. in.	16 x 20 inches
234 sq. ft.	180 sq. in.	240 sq. in.	16 x 24 inches
260 sq. ft.	198 sq. in.	264 sq. in.	20 x 20 inches
286 sq. ft.	216 sq. in.	288 sq. in.	20 x 24 inches
312 sq. ft.	234 sq. in.	312 sq. in.	20 x 24 inches

FLUE SIZES FOR INDIRECT STEAM HEATING

Heating Surface	Area of Cold Air Duct	Area of Hot Air Flue	Size of Register
13 sq. ft.	36 sq. in.	48 sq. in.	8 x 12 inches
26 sq. ft.	54 sq. in.	72 sq. in.	9 x 12 inches
39 sq. ft.	72 sq. in.	96 sq. in.	10 x 14 inches
52 sq. ft.	90 sq. in.	120 sq. in.	12 x 15 inches
65 sq. ft.	108 sq. in.	144 sq. in.	12 x 19 inches
78 sq. ft.	126 sq. in.	168 sq. in.	14 x 22 inches
91 sq. ft.	144 sq. in.	192 sq. in.	14 x 24 inches
104 sq. ft.	162 sq. in.	216 sq. in.	16 x 20 inches
117 sq. ft.	180 sq. in.	240 sq. in.	16 x 24 inches
130 sq. ft.	198 sq. in.	264 sq. in.	20 x 20 inches
143 sq. ft.	216 sq. in.	288 sq. in.	20 x 24 inches
156 sq. ft.	234 sq. in.	312 sq. in.	20 x 24 inches

INDIRECT STEAM RADIATOR TAPPINGS

Radiation in Stack	Radiator Tappings
50 square feet.....	1 $\frac{1}{4}$ inch x 1 inch
60 square feet.....	1 $\frac{1}{4}$ inch x 1 inch
70 square feet.....	1 $\frac{1}{4}$ inch x 1 inch
80 square feet.....	1 $\frac{1}{4}$ inch x 1 inch
90 square feet.....	1 $\frac{1}{2}$ inch x 1 $\frac{1}{4}$ inch
100 square feet.....	1 $\frac{1}{2}$ inch x 1 $\frac{1}{4}$ inch

INDIRECT HOT WATER RADIATOR TAPPINGS

Radiation in Stack	Radiator Tappings
50 square feet.....	1 $\frac{1}{4}$ inch x 1 $\frac{1}{4}$ inch
60 square feet.....	1 $\frac{1}{4}$ inch x 1 $\frac{1}{4}$ inch
70 square feet.....	1 $\frac{1}{2}$ inch x 1 $\frac{1}{2}$ inch
80 square feet.....	1 $\frac{1}{2}$ inch x 1 $\frac{1}{2}$ inch
90 square feet.....	1 $\frac{1}{2}$ inch x 1 $\frac{1}{2}$ inch
100 square feet.....	2 inch x 2 inch

CHAPTER VIII

DIRECT-INDIRECT RADIATION

Describe the direct-indirect system of radiation.

The radiators used in this system of heating are direct radiators, and are located as in direct heating.

Fresh air from the outside is passed through them. This is accomplished by providing the radiator with a box base, the cold air being admitted into it through a cold air duct. The cold air reaches the radiator through an opening at the back of the box base, which is provided with a damper or shut-off.

Is there any difference between the piping for the direct and direct-indirect systems?

Practically none.

What is the rule for estimating direct-indirect radiation?

Estimate the direct radiation necessary for the work in question according to the rule for estimating direct radiation. For direct-indirect radiation, add to this amount 25% for steam, and 33 1/3% for hot water.

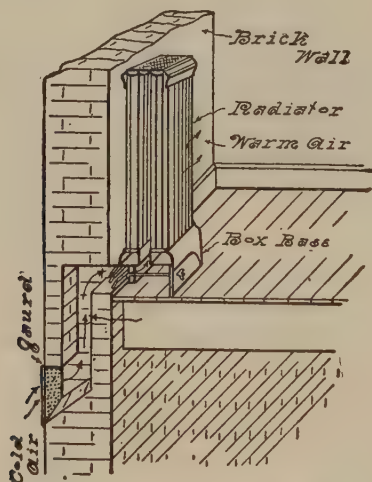


Fig. 12. - Direct-Indirect Radiator.

Why must more radiation be provided for direct-indirect work than for direct?

Warm air surrounds the direct radiator, but a part of the direct-indirect radiator is in contact with cold air, though not so large an amount of surface as in indirect work. Therefore more radiation is needed, in order to make good this loss.

What is the customary manner of using a direct-indirect radiator?

It is customary to use the direct-indirect radiator as a direct radiator, that is, with the damper in the box base closed, until the room is heated to the proper temperature, at which time the damper is opened, and cold air allowed to pass through the radiator.

Where should a direct-indirect radiator be located?

It should be located just as a direct radiator is located, especially as the direct-indirect radiator has to be provided with an inlet through the outer wall, for supplying fresh air to it.

CHAPTER IX

THE CHARACTER AND USE OF VALVES

What style of valve should be used in hot water heating?

Straightway angle valves, commonly called quick-opening radiator valves, are best adapted to this work.

How many valves are used on a hot water radiator?

Only one valve is used on the hot water radiator.

Where should this valve be placed?

On the supply pipe, as close to the radiator as possible.

How many valves are used on a steam radiator?

One valve is used on the one-pipe system, and two on the two-pipe system.

What form of valve should be used on steam radiators?

Valves should be used, which have removable discs, such as known as the Jenkins disc valve.

Why should steam valves with brass seats not be used?

For the reason that the disc will not always close tight.

Where should steam radiator valves be placed?

On one-pipe work the valve should be placed on the flow pipe, and on two-pipe work on both flow and return pipes.

In shutting off a steam radiator, how should the valves be closed?

The valve on the return should be closed first, the supply valve last, and in all cases both valves should be entirely closed or entirely open.

In turning on a steam radiator, how should the valves be opened?

The supply valve should be opened first, then the valve on the return.

How should radiator valves be set?

They should be connected to close against the steam pressure in order that the stuffing boxes may be packed or repacked while the heating system is in operation.

What kind of valves should be used on piping?

Gate valves should be used on piping for the reason that they have a full opening and do not impede circulation.

Why should as few globe valves as possible be used on the piping?

Because they impede circulation.

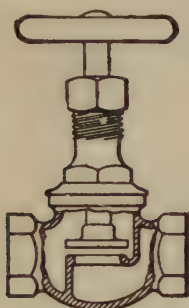


Fig. 13.
Globe Valve.

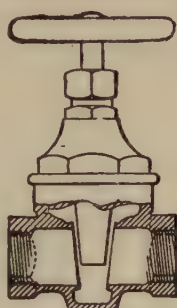


Fig. 14.
Gate Valve.

What advantage has the gate valve over the globe valve?

It has a clearer water way, of the full size of the pipe, and therefore does not impede circulation as the globe valve does. This fact is seen from a comparison of the following illustrations.

If a globe valve is used on a horizontal run of pipe, what precaution is necessary in setting it?

It should be set so that the stem is in a horizontal position. If set differently it will present an obstruction to the passage of condensation.

What is the purpose of the air valve?

It relieves the radiator of air, thus preventing it from becoming air bound, and allowing all its surfaces to fill with steam or water.

What happens if the radiator becomes air bound?

The radiator will not heat.

What are the two types of air valves?

Positive and automatic valves are the types used.

Where should the air valve be placed on a main circuit line?

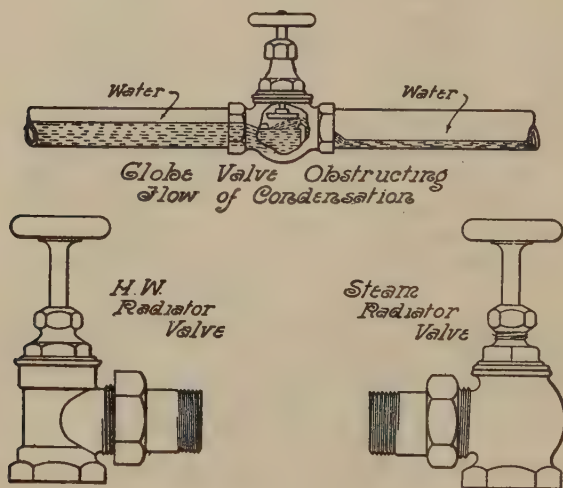
It should always be placed at the point where the pipe drops to the return.

If check valves are used on the return, where should they be placed?

As close to the heater as possible and on the last horizontal run of the wet return.

Where should the draw-off cock be located?

At the lowest point in the system, at a point easily accessible, in order that the entire system may be drained.



CHAPTER X

PIPE AND FITTINGS

How does the capacity of a pipe increase as the diameter increases?

Doubling the diameter of a pipe increases its capacity four times.

How does friction increase in pipes?

Friction increases as the square of the velocity of the water flowing through the pipe.

FRICTION OF WATER IN PIPES

The following table gives the loss in pounds pressure due to friction, in the discharge of given volumes of water per minute, through pipes of different sizes.

Gals per Min.	$\frac{3}{4}$ "	1"	1 $\frac{1}{4}$ "	1 $\frac{1}{2}$ "	2"	2 $\frac{1}{2}$ "	3"	4"	5"	6"
5	3.3	.84	.31	.12	.03					
10	13	3.16	1.05	.47	.12	.03				
15	28.7	6.98	2.38	.97	.27	.06				
20	50.4	12.3	4.07	1.66	.42	.13	.03			
25	78	19	6.4	2.62	.67	.21	.1			
30	....	27.5	9.15	3.75	.91	.3	.12	.03		
35	....	37	12.4	5.05	1.26	.42	.14	.05		
40	....	48	16.1	6.52	1.6	.51	.17	.06		
45	....	....	20.2	8.15	2.01	.62	.27	.07		
50	....	....	24.9	10	2.44	.81	.35	.09	.03	
75	....	....	56.1	22.4	5.32	1.80	.74	.21	.06	.03
100	....	....	....	39	9.46	3.20	1.31	.33	.12	.05
125	....	....	....	....	14.9	4.89	1.99	.51	.17	.07
150	....	....	....	....	21.2	7	2.85	.69	.25	.1
175	....	....	....	....	28.1	9.46	3.85	.95	.34	.14
200	....	....	....	....	37.5	12.47	5.02	1.22	.42	.17
250	....	....	....	....	....	19.66	7.76	1.89	.65	.26
300	....	....	....	....	....	28.06	11.2	2.66	.93	.37

Why should sharp ends be avoided as much as possible?

They decrease the circulation by increasing the amount of friction.

Why should pipes be reamed?

Rough ends of pipe or burs left on same from using ordinary pipe cutters, decrease the size and capacity of the pipe, at the

same time increasing friction, and retarding the flow of water. For this reason, all pipes should be reamed, unless a cutter is used which will not leave a bur.

What fittings may be used on the piping which will aid circulation and reduce friction?

Long turn or long radius fittings will accomplish this result, and are indispensable on hot water work.

How is pipe measured?

Wrought iron pipe as used for heating purposes, is measured on the inside. For instance, $1\frac{1}{2}$ inch pipe for heating purposes is $1\frac{1}{2}$ inches in diameter on the inside, and 1.9 inches in diameter on the outside.

How are boiler tubes measured?

Boiler tubes are measured on the outside.

How are T's and Y's read?

Hold the fitting with the branch pointing up, and the large end to the left. Then read the large end first, small end next, and the branch last, as $1\text{x}\frac{3}{4}\text{x}\frac{1}{2}$ inches.

How should reductions in size of pipe be made in heating?

The proper reductions in size of pipe depend on the character of the work to which the pipe is put.

It is customary to reduce the size of mains by using reducing fittings tapped eccentric, or by using a reducing coupling tapped eccentric, the idea being to have a continuous fall of pipe without the formation of traps or obstructions for holding water at the points where reductions are made. It is customary to reduce the size of pipes for risers or radiator connections, by using a reducing ell on the branch under the floor. Bushings should not be used for reducing purposes, as they are liable to leak and crack, and it is difficult to make them tight under ordinary conditions.

What are eccentric fittings and what are their advantages over common fittings?

Eccentric fittings are so tapped as to bring the bottoms of the openings of different sizes at the same level on the fitting. When these fittings are used they allow a continuous fall of pipe without forming pockets for holding water at the points where reduction in size is made. This is of material benefit to a heating system.

What style of cast iron fittings is preferable?

Those having a flat bead are best, for they are stronger and heavier than the round beaded fittings and can be much more easily tightened, as the various styles of pipe wrenches will take hold better.

What quality of iron is preferable for cast iron fittings?

The strongest fittings, and those least liable to have sand holes are made of the best quality of grey iron.

INTERNAL AREA OF PIPES

Size of Pipe		Internal Area
1 inch.....	.863	square inches
1¼ inch.....	1.5	square inches
1½ inch.....	2.04	square inches
2 inch.....	3.36	square inches
2½ inch.....	4.78	square inches
3 inch.....	7.39	square inches
3½ inch.....	9.89	square inches
4 inch.....	12.7	square inches
4½ inch.....	15.93	square inches
5 inch.....	19.99	square inches
6 inch.....	28.88	square inches

CONTENTS OF PIPES

Size of Pipe	Contents in Gallons Per Foot
1 inch	.04
1¼ inch	.063
1½ inch	.09
2 inch	.163
2½ inch	.255
3 inch	.367
3½ inch	.5
4 inch	.652
4½ inch	.825
5 inch	1.02
6 inch	1.46

PROPORTIONS OF STANDARD PIPE THREADS

Nominal Sizes of Pipe. Inches	Threads per Inch	Total Length of Thread. Inches	Length of Perfect Thread. Inches	Diameter at End of Pipe Outside. Inches	At Bottom of Thread. Inches
$\frac{1}{8}$	27	.41	.19	.393	.342
$\frac{1}{4}$	18	.62	.29	.522	.445
$\frac{3}{8}$	18	.63	.30	.656	.579
$\frac{1}{2}$	14	.83	.39	.816	.717
$\frac{3}{4}$	14	.84	.40	1.025	.926
1	11½	1.03	.51	1.283	1.162
1¼	11½	1.06	.54	1.626	1.505
1½	11½	1.07	.55	1.866	1.745
2	11½	1.10	.58	2.339	2.218
2½	8	1.64	.89	2.819	2.646
3	8	1.70	.95	3.441	3.268
3½	8	1.75	1.00	3.938	3.765
4	8	1.80	1.05	4.434	4.261
4½	8	1.85	1.10	4.931	4.758
5	8	1.91	1.16	5.491	5.318
6	8	2.01	1.26	6.546	6.373
7	8	2.11	1.36	7.540	7.367
8	8	2.21	1.46	8.534	8.361
9	8	2.32	1.57	9.527	9.354
10	8	2.43	1.68	10.645	10.472

CAPACITIES AND THREADS OF STANDARD
WROUGHT IRON PIPE

Nominal Inside Diameter Inches	Length of Thread Inches	Length of Pipe Containing One Gallon—Feet	Contained Lbs. of Water per Lineal Foot
$\frac{1}{8}$	9/32	336.6	.024
$\frac{1}{4}$	$\frac{3}{8}$	148.8	.044
$\frac{3}{8}$	7/16	100.8	.082
$\frac{1}{2}$	$\frac{1}{2}$	63.2	.132
$\frac{3}{4}$	9/16	36.1	.23
1	$\frac{5}{8}$	22.3	.373
1¼	11/16	12.8	.648
1½	13/16	9.4	.883
2	$\frac{7}{8}$	5.7	1.454
2½	1	4.02	2.072
3	1	2.6	3.202
3½	1 1/16	1.95	4.285
4	1½	1.51	5.517
4½	1¾	1.2	6.908
5	1¾	.96	8.668
6	1¾	.66	12.521
7	1½	.49	16.79
8	1¾	.38	21.688
9	1¾	.3	27.58
10	1¾	.24	34.171
11		.2	41.189
12		.17	49.017
13		.139	59.762
14		.12	69.125
15		.102	81.07
16		.091	91.559

DIMENSIONS AND CAPACITIES OF STANDARD
WROUGHT IRON PIPES

Nominal Inside Diameter	Actual Diameter Inches		Area Square In. Inside	Lineal Feet per sq. ft. External Surface	Nominal wt. Pounds per Lineal Foot	Length of Full Thread	Size of Tap Drill	Gallons of Water per 100 Ft. of Length
	Inside	Outside						
$\frac{1}{8}$	.27	.41	.06	9.43	.24	.19	21/64	.3
$\frac{1}{4}$	.36	.54	.10	7.08	.42	.29	29/64	.5
$\frac{3}{8}$	.49	.68	.19	5.66	.56	.30	19/32	1.0
$\frac{1}{2}$	.62	.84	.30	4.55	.83	.39	23/32	1.6
$\frac{3}{4}$	.82	1.05	.53	3.64	1.12	.40	15/16	2.7
1	1.05	1.32	.86	2.90	1.67	.51	1 3/16	4.5
1 $\frac{1}{4}$	1.38	1.66	1.50	2.30	2.24	.54	1 15/32	7.7
1 $\frac{1}{2}$	1.61	1.90	2.04	2.01	2.68	.55	1 23/32	10.6
2	2.07	2.38	3.36	1.61	3.61	.58	2 3/16	17.4
2 $\frac{1}{2}$	2.47	2.88	4.78	1.33	5.74	.89	2 11/16	24.8
3	3.07	3.50	7.38	1.09	7.54	.95	3 5/16	38.4
3 $\frac{1}{2}$	3.55	4.	9.89	.96	9.	1.	3 13/16	51.3
4	4.03	4.50	12.73	.85	10.67	1.05	4 7/32	66.1
4 $\frac{1}{2}$	4.51	5.	15.96	.76	12.34	1.10	4 21/32	82.9
5	5.05	5.56	19.99	.69	14.50	1.16	5 15/64	103.8
6	6.07	6.63	28.89	.58	18.76	1.26	6 1/4	150.0
7	7.02	7.63	38.74	.50	23.27	1.36	7 5/16	202.0
8	7.98	8.63	50.02	.44	28.18	1.46	8 5/16	260.0
9	8.94	9.63	62.73	.40	33.70	1.57	9 5/16	326.0
10	10.02	10.75	78.82	.36	40.07	1.68	10 5/16	410.0
11	11.	11.75	95.03	.33	45.00	1.79	11 5/16	495.0
12	12.	12.75	113.09	.30	48.99	1.90	12 5/16	590.0

CHAPTER XI

STEAM HEATING

What are some of the relative advantages of steam and hot water heating?

The first cost of a steam heating system is considerably less than that of a hot water system, probably from 20 to 25 per cent. less. This is due to the smaller sizes of pipes and radiators used on steam work. However, the cost of operation is in favor of the hot water system.

When steam radiators are shut off because of too great heat, they cool much more rapidly than hot water radiators, but in many cases this fact may prove to be an advantage on the side of the hot water system.

A steam plant requires more attention and skill on the part of the attendant than the hot water system. As to freezing, the preference is with steam, and in public buildings, this is often a matter of importance. A hot water system may be run during mild weather to give off much less heat than a steam system, which must always be brought to a temperature of 212 degrees before any heat whatever is felt. Another advantage which the hot water system has, is that hot water may be heated below the water line of the boiler.

What systems of steam heating are in general use?

The low pressure gravity system, and the high pressure system, each being installed according to several different methods.

What is the chief feature of the low pressure gravity system of steam heating?

In this system all condensation returns to the boiler by gravity, that is, by its own weight.

What is known as low pressure steam?

Any pressure of steam below 10 pounds above atmospheric pressure is low pressure steam. This is the form of steam heating generally used in house heating.

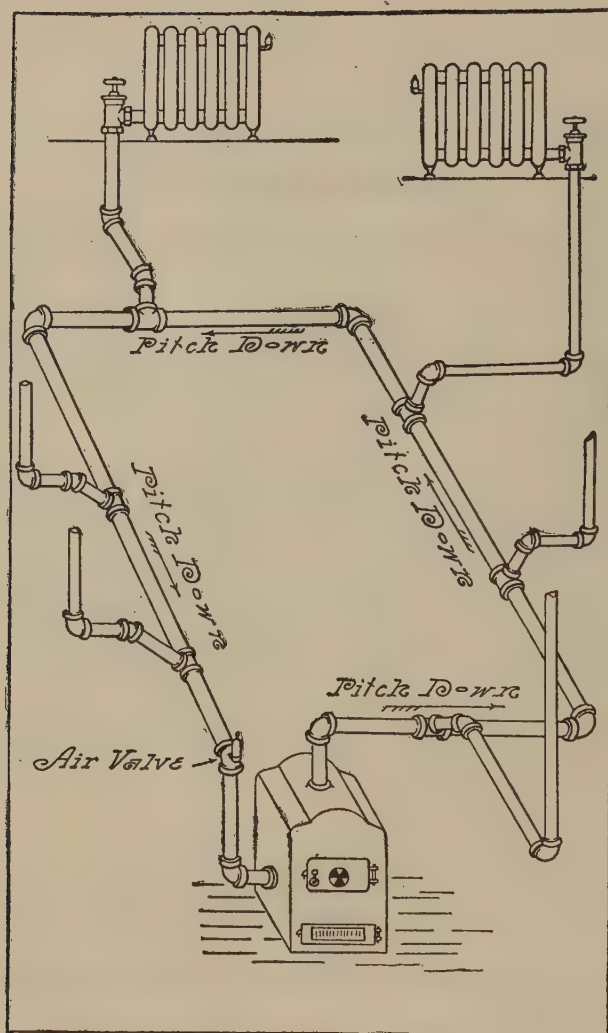


Fig. 15—Circuit System of Steam Heating

Why is the low pressure steam system mostly used in house heating?

For the reason that it is safer than high pressure steam, and as it works at a lower pressure is more economical to run, and requires less attention.

What is the general meaning of steam main?

A steam main is a flow pipe taken off the boiler and running horizontally on the basement ceiling to supply steam to the various branch lines which supply radiation.

What is a riser?

A riser is a pipe running vertically from the end of a branch to the radiation located at points above.

What is a drop riser?

A drop riser is the term applied to lines which are taken out of the mains in an overhead steam heating system. These mains run at the top of the building, and the drop risers extend downward to the basement, supplying radiation on the way down, the condensation passing down with the steam.

What is a return?

A return is a pipe for carrying water of condensation from the end of a main and from other points, back to the boiler. Return pipes may be run above the water-line of the boiler, or below it.

What is the smallest main that should be run on a steam heating system?

Nothing less than $1\frac{1}{2}$ inch should be used for a steam main, and this size should not be run for a greater length than 25 feet.

What is the smallest riser that should be used on a steam system?

Regardless of the amount of work to be done, no steam riser less than 1 inch in size should be used.

Why should the use of small pipes be avoided in steam heating?

If too small, pipes will sometimes cause the raditors to fill with water. They also cause an increase of friction, which lessens the circulation.

How high should the steam main rise above the boiler?

It should be run as high as possible. A distance of 18 inches or more is desirable if conditions will allow it.

How should branches be taken from steam supply mains?

From the top, or at an angle of 45°, but never from the side. The 45° connection is preferable.

Why should branches not be taken from the side of the main?

Water hammer and the forcing of condensation from the main into the radiation may result.

How should a branch be run?

It should be run full size from the main to the riser, and connected with the latter by a reducing elbow.

What should be the relative size of a horizontal branch and its riser?

The horizontal branch should be one size larger than the riser, if more than 6 or 8 feet in length.

Why should the branch be larger than the riser?

Circulation is not so strong on a horizontal as on a vertical line.

Why should straight elbows on the main be avoided as far as possible?

They cause friction, which impedes circulation.

What pitch is necessary on a steam main?

A steam main should have a pitch of at least $\frac{1}{2}$ inch to 1 inch for every 10 feet of length.

What pitch is necessary on branches?

Branches should have a pitch of at least 1 inch for each 5 feet.

Why should a perfect alignment be secured in the running of steam pipes?

Carelessness in the running of steam pipes is liable to form pockets or traps which impede the circulation and cause hammering, due to the water of condensation remaining in the pockets.

When necessary to form a pocket in a steam main, what precaution should be taken to relieve it of condensation?

When found necessary to make a direct rise in order to get over an obstruction or increase head room, the pocket formed because of this, should be dripped by a small pipe commonly termed a bleeder, into a wet return,

What precaution is necessary when radiators are located near the water line of the boiler, and a wet return is used?

A check valve should be placed on the return.

How should a steam heating plant be tested?

It may be tested at any season of the year, by the following rule, as laid down by Prof. Carpenter.

The following table shows the relative difference there should be between the outside and inside temperatures, to provide for a temperature of 70° when the outside air is at zero, with a pressure of 3 pounds.

Temperature of Outside Air	Temperature of Room
.10 degrees.....	64.7 degrees
0 degrees.....	70. degrees
10 degrees.....	75.1 degrees
20 degrees.....	81. degrees
30 degrees.....	86.5 degrees
40 degrees.....	93.1 degrees
50 degrees.....	98.7 degrees
60 degrees.....	104.7 degrees
70 degrees.....	110.5 degrees
80 degrees.....	117.1 degrees
90 degrees.....	123.5 degrees

What is the usual requirement as to temperature for residence heating?

It is customary for the heating contractor to guarantee to heat a residence to a temperature of 70 degrees in zero weather.

What causes water hammer in steam piping?

Traps or pockets in the piping, which allow water of condensation to lodge in them, are the cause. Steam, in passing such points, frequently makes a noise as if the pipe were being pounded with a hammer.

How can this trouble be avoided?

By carefully grading the steam main, allowing no traps or pockets, or whenever this occurs, dripping them into a wet return.

TEMPERATURE OF STEAM AT VARIOUS TEMPERATURES.
PRESSURE IN POUNDS

By Steam Gauge	Above Atmosphere	Degrees Temperature
0	15	212
5	20	228
10	25	240
15	30	250
20	35	259
25	40	267
30	45	274
35	50	281
40	55	287
45	60	292
50	65	298
55	70	302
60	75	307
65	80	312
70	85	316
75	90	320
80	95	324
85	100	327
90	105	331
95	110	334
100	115	338
110	125	344
120	135	350
130	145	355
140	155	361
150	165	366

What is the best method of running pipe around a timber which cannot be removed or avoided?

This is best accomplished by the use of offset fittings, as they present the least resistance to circulation.

What is an equalizing pipe and its purpose?

It is a pipe connected from the steam dome or top of the boiler to one of the return openings below the water line of the boiler, or it may be connected from the main near the point where it is taken from the boiler, and connected into the return pipe at a point near the entrance of the return into the boiler. Its purpose is to steady the water line of the boiler, which may fluctuate, and cause annoyance, this trouble being due to the peculiar construction of the boiler or to the fact that a proper height cannot be reached by the main above the boiler, owing to a low ceiling or other cause.

What are the two systems of low pressure steam heating in common use?

The one-pipe and the two-pipe systems. The one-pipe system is installed as a circuit, divided circuit or as a relief system with

no returns. The two-pipe system is installed either by the regular method or as an overhead system. When the regular system is used, both flow and return mains are run in the basement, while in the case of the overhead system the mains are carried overhead with the returns in the basement.

Explain the meaning of high pressure steam as used in heating operations.

This generally applies to the use in heating operations of tubular or high pressure boilers which are primarily used for power purposes.

What pressures are used in high pressure steam work?

Pressures from 30 or 35 pounds up to 100 pounds or more are used in such work.

Is steam at high pressure generally used in a heating plant?

Steam at high pressure is not generally so used, but is first reduced by a pressure reducing valve located on the steam line, which reduces it to normal pressure.

Describe the exhaust heating system.

When steam which is under high pressure is supplied to an engine or other apparatus which uses steam in its operation, it does its work and finally escapes through the exhaust pipe. Only a comparatively small part of the heating power is used up when the steam is exhausted, and instead of allowing it to pass out into the air and be entirely wasted, it is made use of in a heating system. This method is called exhaust heating.

What is meant by a relief system?

This is a heating system in which all main flow pipes pitch upward from the boiler, and in which each has a drip or relief pipe connected at a point near the boiler, which carries all condensation to the bottom of the same. Condensation from the piping and radiators may also be relieved by drip connections on each riser or radiator connection. These should connect to a wet return.

DRIP PIPES FOR STEAM MAINS

Diameter of Steam Main in Inches	Length of Steam Main in Feet			
	1 to 100	100 to 200	200 to 400	400 to 600
Diameter of Drip Pipe in Inches				
1½ to 2	½	½	½	¾
3	½	¾	¾	1
4	¾	¾	1	1¼
5	¾	1	1¼	1½
6	1	1¼	1½	1½
7	1	1¼	1½	1½
8	1	1¼	1½	2
9	1	1¼	1½	2
10	1¼	1¼	1½	2

SIZE OF DRIPS FOR RISERS

Square Feet of Radiation to Be Drained	Diameter of Pipe in Inches
0 to 50	— ¾
50 to 100	— 1
100 to 250	— 1¼
250 to 500	— 1½

These sizes are based on relieving condensation from the main pipe. If condensation from radiation enters the main, sizes should be increased in proportion.

CHAPTER XII

ONE-PIPE SYSTEM OF STEAM HEATING

What are the most common forms of one-pipe steam heating?

We sometimes designate the various styles of running the main as systems. There is the circuit system in which the main is run in the form of a loop around the basement, the branches to radiators and the risers being taken from this loop. There is also the overhead system, in which the main is carried to the ceiling of the highest room to be heated, and from there run in a circuit around the room or rooms, the pipes or branches dropping down to feed the various radiators on the floors beneath. This system is much used in buildings having no cellars.

What is the relative size of steam mains of the one-pipe and two-pipe systems?

The main pipe of the one-pipe system is the larger.

Why should it be larger?

For the reason that in the one-pipe system one pipe does the work of both supply and return.

In what way does the matter of valves give the one-pipe system an advantage over the two-pipe system?

There is only one valve to operate, and no mistake can be made. When there are two valves, the opening or closing of them improperly frequently causes trouble.

SIZE OF STEAM MAINS—ONE-PIPE SYSTEM

Size of Main		Radiation Supplied	
1	inch.....	40 to	50 square feet
1¼	inch.....	100 to	125 square feet
1½	inch.....	125 to	250 square feet
2	inch.....	250 to	400 square feet
2½	inch.....	400 to	650 square feet
3	inch.....	650 to	900 square feet
3½	inch.....	900 to	1250 square feet
4	inch.....	1250 to	1600 square feet
4½	inch.....	1600 to	2050 square feet
5	inch.....	2050 to	2500 square feet
6	inch.....	2500 to	3600 square feet
7	inch.....	3600 to	5000 square feet
8	inch.....	5000 to	6500 square feet
9	inch.....	6500 to	8100 square feet
10	inch.....	8100 to	10000 square feet

How are the returns for the one-pipe system constructed?

The one-pipe system may have either dry or wet returns.

What is a dry return?

When the drip or return from end of main or from radiator is carried back to the boiler above the water line, it is called a dry return.

What is a wet return?

When the water of condensation is carried back to the boiler below the water line, the return is called a wet return.

Why is a dry return preferable to a wet return?

Because the water of condensation is returned to the boiler much more easily by the dry return.

How should a horizontal dry return be run?

It should run not less than 12 inches above the water line, and 15 inches would be preferable.

Where is the use of check valves advisable on the one-pipe system?

On wet returns.

Why are they necessary?

Sometimes the required height between the end of the main and the water line cannot be given, owing to a low cellar or other cause, and a check valve on the return will often prevent the water backing up through the return into the main.

Where should check valves be placed?

On the horizontal part of the return, and as close to the boiler as possible.

On one-pipe work, what care should be taken in setting radiators?

Care should be taken that the flow end of the radiator is not higher than the opposite end. It should be level, or the flow end lower than the opposite end.

CHAPTER XIII

THE CIRCUIT SYSTEM OF STEAM HEATING

Describe the circuit system of steam heating.

In this system the flow pipe is run from the boiler vertically to the ceiling of the basement, from which point it pitches downward throughout its course around the cellar or basement, to a point at or near the rear of the boiler, where an automatic air vent is placed, and drop made with a return pipe into the return opening of the boiler.

In what form of buildings is the circuit system used?

Generally in those buildings which are square or rectangular in shape.

Describe the divided circuit system of steam heating.

The divided circuit is the same in every way as the regular circuit system, except that the main is run in two circuits in different directions.

How should returns be connected on the divided circuit system?

Mains generally end at quite a distance from the boiler, with an automatic air valve on the end of each main. The return from the end of each should drop and connect together at a point below the water line, and return to the boiler wet.

Under what circumstances may two circuits be taken off the same heater?

When the building is of such shape that one circuit will not do the work to advantage, that is to say, in long buildings, where the boiler is set at or about the middle of the building, and it is desirable to run a loop in either direction.

What are some of the advantages of the circuit system?

It is simple in construction, requires less labor and material, is very efficient, and the piping is all overhead.

How high should the main be at the point where it drops into the return?

At least 14 inches above the water line of the boiler. 18 inches is better.

Should the main be reduced in size on a circuit system?

Generally it is carried full size throughout, and reduced two or more sizes as it drops to the return.

Why should no reduction be made in the size of main?

Condensation from the different radiators is constantly entering the main, lessening its capacity as it passes the different branches.

What is the purpose of the air valve on the circuit system?

Its purpose is to free the main of air, without forcing it upward into the radiation.

How should branch connections be made with the main?

At an angle of 45° , with a 45° ell.

Why is this connection preferable to the top connection?

When the condensation returns at an angle of 45° , it enters the main flow pipe on the side, and does not impede the flow to the extent that it would in entering on top.

If the horizontal branch is 6 feet or more in length, what should its size be?

It is well in this case to increase it one size, reducing to the usual size at the radiator spud or riser.

If the condensation does not drain out, what is the result?

The radiator will not heat properly, and water hammer will occur.

CHAPTER XIV

THE OVERHEAD SYSTEM OF STEAM HEATING

Describe the overhead system of steam heating.

In this system, the feed pipe is carried vertically to the ceiling of the top floor, or into the attic, and from this point branches are carried down to the different radiators.

In what style of buildings is the overhead system largely in use?

In office buildings, school houses, factories, etc., and often in residences, when the main can be carried up into an attic. Frequently, owing to the absence of a basement under the building, it is necessary to use the overhead system to heat the radiators.

How should radiators be connected on the overhead system?

Return pipes should enter the top of the flow end of the radiator, and return out of the bottom of the return end.

Some radiators on the one-pipe system may be connected single pipe. Radiators on the overhead system may also be connected as on the one-pipe system. Where this is done, the condensation from the radiator returns into the drop or feed pipe, as seen in Fig. 16.

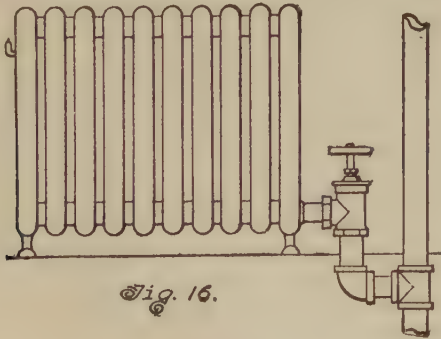


Fig. 16.

SIZE OF STEAM MAINS, ONE-PIPE SYSTEM

Direct Radiation Sq. Ft. of Htg. Surface Supplied	Length of Main in Feet									Size of Return
	20	40	80	100	200	300	400	600	1000	
	Diameter of Pipe in Inches									
150	1½	1½	1½	1½	2	2½	2½	3	3	1
300	2	2	2	2	2½	3	3	3	4	1¼
450	2	2½	2½	2½	3	3	3½	3½	4	1¼
900	2½	2½	3	3	3½	3½	4	4	4½	1½
1200	3	3	3½	3½	4	4	4½	4½	5	2
1600	3½	4	4	4	4½	4½	5	5	6	2
2000	4	4	4½	4½	5	5	6	6	7	2½
2500	4	4½	4½	5	6	6	6	7	8	3
4500	5	5	5	6	7	7	7	8	9	3
6500	5	6	7	7	8	8	8	9	10	3½
9000	6	7	8	8	9	9	9	10	11	4
11000	7	8	8	9	10	10	10	11	12	4½

Note: Size of returns as given in the table for "Wet" returns. For "Dry" returns one size larger pipe should be used.

CHAPTER XV

THE TWO-PIPE SYSTEM OF STEAM HEATING

Describe the piping for the two-pipe system of steam heating.

The main flow pipe is carried direct to the ceiling, and then pitches downward until the last branch has been taken out, at which point the condensation should be carried off by means of a relief pipe connected into the nearest return.

How are returns run in this system?

Wet returns are usually run, the wet return being preferable to the dry return in this system.

How should branches be taken off the main?

Either on top or at an angle of 45 degrees.

How should branches pitch?

They should pitch up from the main to allow condensation in the branch to drain back into the main.

If necessary to pitch a branch downward, what precaution should be taken?

A relief pipe should be taken from the end of the branch, where the pipe rises, and connected into a return, below the water line.

How should returns be made?

Whenever possible on the two-pipe system, a separate return from each radiator should be run to the main return.

Why are separate returns preferable?

They make a stronger circulation.

What should be the relative size of flow and return pipes?

The return should usually be one size smaller than the flow.

SIZE OF MAINS AND RETURNS FOR THE TWO-PIPE SYSTEM

Flow	Return	Radiation Supplied	
$\frac{3}{4}$ inch	$\frac{3}{4}$ inch	40 to	50 sq. ft.
1 inches	$\frac{3}{4}$ inch	100 to	125 sq. ft.
$1\frac{1}{4}$ inches	1 inch	125 to	250 sq. ft.
$1\frac{1}{2}$ inches	$1\frac{1}{4}$ inches	250 to	400 sq. ft.
2 inches	$1\frac{1}{2}$ inches	400 to	650 sq. ft.
$2\frac{1}{2}$ inches	2 inches	650 to	900 sq. ft.
3 inches	$2\frac{1}{2}$ inches	900 to	1250 sq. ft.
$3\frac{1}{2}$ inches	3 inches	1250 to	1600 sq. ft.
4 inches	$3\frac{1}{2}$ inches	1600 to	2050 sq. ft.
$4\frac{1}{2}$ inches	4 inches	2050 to	2500 sq. ft.
5 inches	$4\frac{1}{2}$ inches	2500 to	3600 sq. ft.
6 inches	5 inches	3600 to	5000 sq. ft.
7 inches	6 inches	5000 to	6500 sq. ft.
8 inches	6 inches	6500 to	8100 sq. ft.
9 inches	6 inches	8100 to	10000 sq. ft.

How should two returns be connected together?

In order to prevent steam passing in two different directions to the radiators, with the consequent cutting off of return water from radiators, all returns should connect below the water line.

What connection should be made at the end of each steam main or branch?

A drip from same should be taken into a wet return.

How should the drip from a main be connected into the return?

With a wet return the drip may be connected directly into it, but with a dry return the drip should be provided with a loop or trap before entering the return.

Why is a loop or trap necessary in the connection of a drip into a dry return?

To prevent short circuiting of steam and the consequent blocking of return water.

What are the relative sizes of horizontal branches and their risers on the two-pipe system?

They may be of the same size unless the branch is of more than ordinary length, in which case it is well to increase the horizontal branch one size.

What precaution is necessary in reducing the size of mains on this system?

As branches are taken off, the main may be reduced, but the

reduction should be much less than in proportion to the areas of these branches.

How should reductions be made?

By means of eccentric tees or couplings. Otherwise heel drips must be taken from the main to the wet return.

How should main returns increase in size?

The return should start beyond the last branch, pitch toward the boiler below the water line, and increase in size as other returns enter it. It usually runs one size smaller than the corresponding supply pipe except in the case of large sizes, where the difference is sometimes greater.

When is the use of check valves advisable on the two-pipe system?

Their use is advisable on wet returns of small size or uncommon length.

Where should check valves be placed?

On the horizontal return, as close to the boiler as possible.

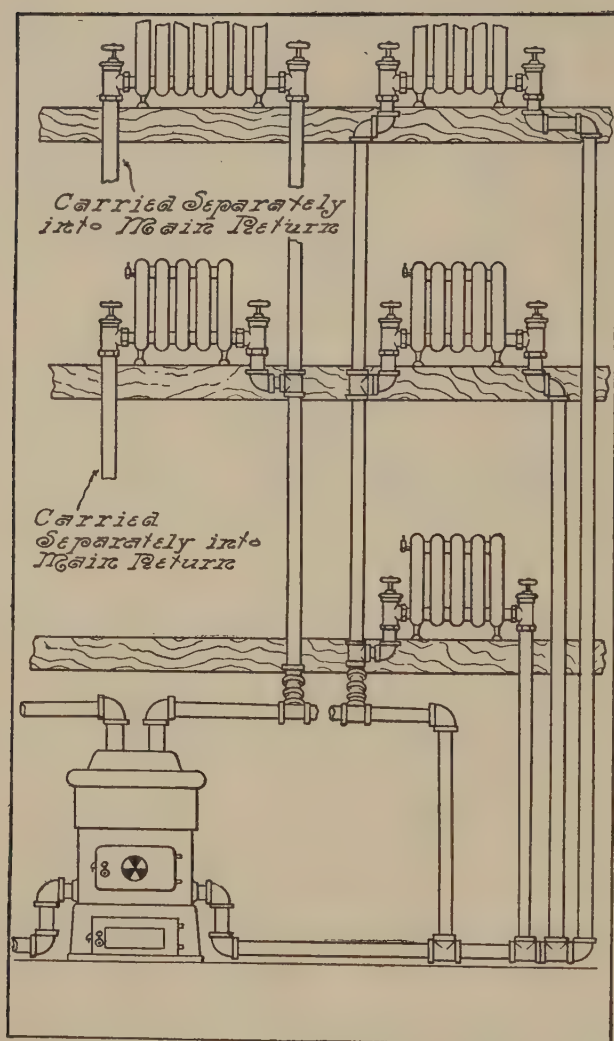


Fig. 17—Two-Pipe System of Steam Heating

CHAPTER XVI

HOT WATER HEATING

What systems of hot water heating are in general use?

The open tank, and the closed tank or pressure systems.

Which of these systems is preferable for house heating?

The open tank system is preferable to the closed tank system, as it may be more easily and safely operated.

What is the principal difference between the open and closed tank systems?

On the open tank, a vent pipe is carried from the expansion tank through the roof or side of the building, open to the atmosphere. The closed tank is not vented, and is therefore under pressure.

What advantage has the closed tank system?

In this system the water may be heated to a temperature above 212 degrees, the boiling point of the open tank system.

What precaution is necessary on the closed tank system?

A safety valve should be placed on the expansion tank, with a pipe running from the open side of the valve to the atmosphere, in order that when sufficient pressure is raised to operate the valve, an overflow of water may be carried off without damage to the property.

At what point should the safety valve be set on the closed tank system?

10 pounds is considered to be the proper pressure at which the safety valve should work.

What difference is there between the piping for the open and for the closed tank system?

The piping for the closed tank system may be somewhat smaller than for the open tank system, but the piping is run and connections taken off in the same manner for each system.

In running mains for hot water work, what pitch should be obtained to secure good service?

From $\frac{1}{2}$ inch to 1 inch for each 10 feet of length.

What pitch should hot water branches have?

Double the pitch used on the main.

How should hot water mains pitch?

Upward from the boiler.

On hot water work, what should be the comparative size of flow and return pipes?

They should be of equal size.

How should flow and return pipes be run?

They should be run parallel to each other if possible.

What governs the size of hot water mains?

The sizes of the various branches, and the amount of radiation fed by them.

SIZES OF HOT WATER MAINS

Sizes of Mains	Radiation Supplied
1 $\frac{1}{4}$ inch.....	75 to 125 square feet
1 $\frac{1}{2}$ inch.....	125 to 175 square feet
2 inch.....	175 to 300 square feet
2 $\frac{1}{2}$ inch.....	300 to 475 square feet
3 inch.....	475 to 700 square feet
3 $\frac{1}{2}$ inch.....	700 to 950 square feet
4 inch.....	950 to 1200 square feet
4 $\frac{1}{2}$ inch.....	1200 to 1575 square feet
5 inch.....	1575 to 1975 square feet
5 $\frac{1}{2}$ inch.....	1975 to 2375 square feet
6 inch.....	2375 to 2850 square feet

What should be the relative size of horizontal branches and risers?

Branches from the main, at or near the boiler, may be of the same size as the riser or pipe supplying the radiator. Towards the extreme end of the main, it is well to make the branch or horizontal pipe one size larger than the riser or radiator connection. This is equally true of an extremely long branch. A horizontal pipe or branch, longer than 6 feet, should be increased one size over that of the riser or radiator connection which it supplies.

What is the smallest hot water main that can be safely used?

1½ inch is the smallest practicable size, and this should not be used for more than a length of 25 feet.

NUMBER AND SIZES OF BRANCHES MAINS WILL SUPPLY

Main	Number and Size of Branches
1 inch.....	2 ¾-inch Branches
1¼ inch.....	2 1-inch Branches
1½ inch.....	2 1¼-inch Branches
2 inch.....	2 1½-inch Branches
2½ inch.....	2 1½-inch and 1 1¼-inch Branches
2½ inch.....	1 2-inch and 1 1¼-inch Branches
3 inch.....	1 2½-inch and 1 2-inch Branches
3½ inch.....	2 2½-inch Branches
3½ inch.....	3 2-inch Branches
3½ inch.....	1 3-inch and 1 2-inch Branches
4 inch.....	1 3½-inch and 1 2½-inch Branches
4 inch.....	2 3-inch Branches
4 inch.....	4 2-inch Branches
4½ inch.....	6 2-inch Branches
4½ inch.....	1 3½-inch and 1 3-inch Branches
4½ inch.....	1 4-inch and 1 2½-inch Branches
5 inch.....	1 4-inch and 1 3-inch Branches
5 inch.....	1 4½-inch and 1 2½-inch Branches
5 inch.....	8 2-inch Branches
6 inch.....	4 3-inch Branches
6 inch.....	10 2-inch Branches
6 inch.....	1 3-inch and 2 4-inch Branches

How should branch pipes be taken off the main?

From the top of the main, or at an angle of 45 degrees, the 45 degree connection being preferable.

Why is the connection of a branch at an angle of 45 degrees the preferable connection?

For the reason that this connection, made by tipping the tee at 45 degrees, and using a nipple and 45 degree ell, causes less friction in the flow of water than any other method of connection. Any choking or retarding of circulation should be done at the end of the branch as shown by illustrations under "Radiation."

Many fitters think that by taking the branch out of the top they are increasing the circulation, but they are using a 90 degree ell, and this causes an amount of friction ordinarily found by turning a column of water at right angles. This is not true of the 45 degree connection. The above applies to steam as well as to hot water work.

What precaution is necessary in reducing the size of mains?

They should not be reduced too rapidly as branches are taken

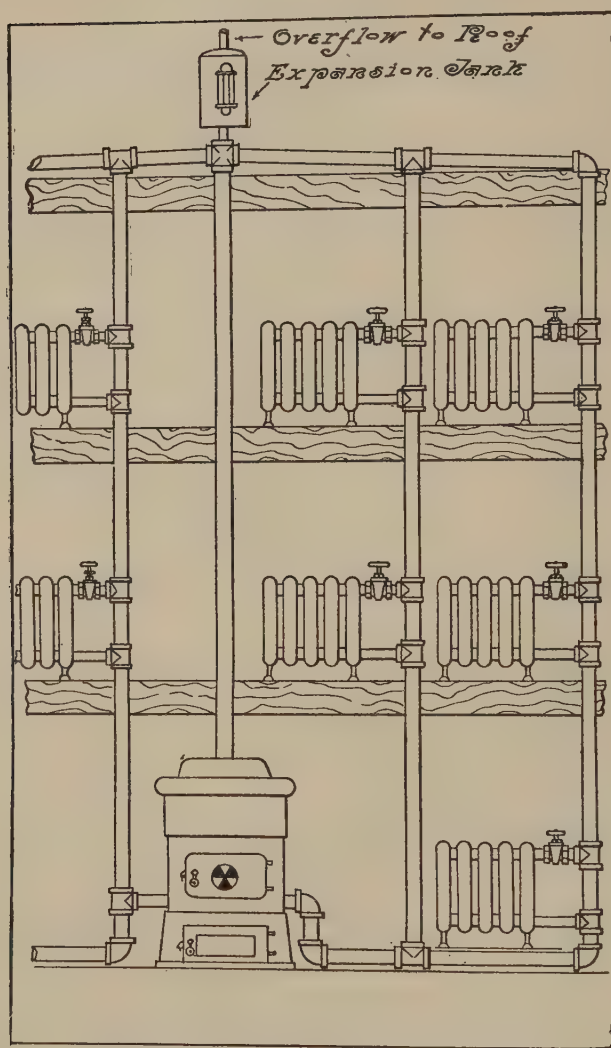


Fig. 18—Overhead System of Hot Water Heating

off, for the greater amount of friction in the smaller sizes of pipe will often cause trouble.

With radiator and riser close together, which should be taken off first?

The radiator connection should be made first.

Why should the radiator connection be made first?

In order to favor the radiator in the matter of circulation.

Can radiators be heated by hot water on the same level as the boiler, or below it?

They can be heated in these positions. Under such conditions, circulation results from the weight of water above the low radiators. This depends on the fact that a column of water 2 feet in height will produce about 1 pound of pressure.

How can a radiator or coil be heated below the line of the top of the boiler?

By carrying the flow pipe up so as to get a pressure from the weight of water above, to produce circulation.

From what point should a hot water system be filled?

From the lowest point.

Why should it be filled in this manner?

For the reason that this method will drive the air out of the system as the water rises.

What should be done with the air vents in filling a hot water system?

They should all be opened, to allow the air to escape, being closed one by one as each radiator is completely filled with water.

HOT WATER DIRECT RADIATOR TAPPINGS

Size of Radiator	Tappings for First Floor
15 square feet and less.....	$\frac{3}{4}$ inch
15 to 50 square feet.....	1 inch
50 to 100 square feet.....	1 $\frac{1}{4}$ inch
100 square feet and larger.....	1 $\frac{1}{2}$ inch

	Tappings for Second Floor
20 square feet and less.....	$\frac{3}{4}$ inch
20 to 70 square feet.....	1 inch
70 to 125 square feet.....	1 $\frac{1}{4}$ inch
125 square feet and larger.....	1 $\frac{1}{2}$ inch

HOT WATER INDIRECT RADIATOR TAPPINGS

Size of Radiator	Tapping
40 square feet and less.....	1 inch
40 to 90 square feet.....	1¼ inch
90 to 150 square feet.....	1½ inch
150 square feet and larger.....	2 inch

At what temperature should water leave the boiler to obtain satisfactory results from a hot water heating system?

Generally at about 180 degrees.

At what temperature should water return to the boiler?

With water leaving the boiler at 180 degrees, it should return at least at 160 degrees.

What is the least amount of loss in heat that should occur in hot water heating?

There should not be a loss of more than 20 per cent. in traversing the building, if good results are to be obtained.

Under the flow and return temperatures named above, what will be the temperature at the radiators?

The average temperature at the radiators would be about 170 degrees.

How should the grate surface and heating surface of a hot water heater be proportioned?

On small work, the area of grate surface should be 1 square foot for 30 square feet of heating surface. On work where there is more than 500 feet of radiation, the ratio may be 1 to 40. As an example—For 1000 square feet of radiation, 125 square feet of heating surface is necessary, with a fraction over 4 square feet of grate surface.

What precautions should be observed in running hot water risers?

In running risers for hot water work, it is well to avoid outside walls. If risers are to be concealed they should be run up through inside walls. If necessary, for any unavoidable reason, to run risers through or against an outside wall, they should be carefully covered to prevent chilling or freezing.

CHAPTER XVII

THE CIRCUIT SYSTEM OF HOT WATER HEATING

Describe the piping for the circuit system of hot water heating.

The main is carried entirely around the cellar or basement, from the top of the boiler, dropping into the return of the boiler after the last radiator has been passed.

Is it best to use one or more circuits in this system?

When possible, only one circuit should be used, but owing to the shape of the basement, it is often best to run two circuits.

What pitch should the main have, down from the boiler?

At least $\frac{1}{2}$ inch for each 10 feet of length.

Should the main be run full size, or reduced?

It should be run full size until it enters the return of the boiler.

What is the highest point on the circuit?

Directly above the boiler.

How should the air be relieved at the high point?

By making connection to expansion tank at that point.

What size pipe should be used on a circuit main?

A size somewhat larger than that of the ordinary hot water main when it leaves the boiler, for the reason that in this system, the one pipe does the work of both the flow and return on other systems.

SIZE OF CIRCUIT MAINS

Size of Main	Direct Radiation Supplied
2 inch.....	175 square feet
2½ inch.....	300 square feet
3 inch.....	500 square feet
3½ inch.....	700 square feet
4 inch.....	1000 square feet
4½ inch.....	1200 square feet
5 inch.....	1600 square feet
5½ inch.....	2000 square feet
6 inch.....	2400 square feet

How do the flow and return occupy the same pipe in this system?

The hot water of the flow occupies the upper part of the pipe, and the colder return water the lower part.

How should the circuit be run after passing the last radiator?

It may be carried across, and drop at the boiler, or it may drop at once after passing the radiator.

The former method is preferable.

How does the piping of the circuit system above the basement, compare with that of other hot water systems?

It is the same.

How are branch flow pipes taken out of the main?

From the top.

How are returns connected into the main?

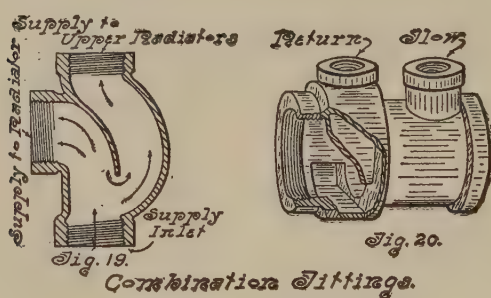
On the side.

Are combination fittings used on the circuit system?

They are used with good results, the flow connection being off the top, and the return into the side.

What advantage is gained in the use of combination fittings?

They save labor and expense.

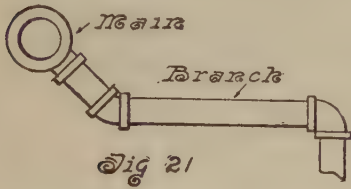


CHAPTER XVIII

THE OVERHEAD SYSTEM OF HOT WATER HEATING

Describe the piping of the overhead system of hot water heating.

The main flow pipe is run vertically to the ceiling of the top floor, or to the attic, as the case may be, from which point horizontal branches are run with a downward pitch of at least 1 inch in 10 feet, to the different supply pipes, which drop down through the rooms, feeding a radiator or a line of radiators. The branching in the attic, as regards size of pipe and pitch, is quite similar to the main and branches of a one-pipe gravity steam system, except that the tee is pitched downward at 45 degrees, and a 45 degree ell and nipple is used on the supply branch, as shown in the accompanying illustration.



In the basement the bottoms of these drop or supply pipes are connected into a line of return pipes of similar size to the flow or branches in the attic, which return to the boiler with practically the same size as the flows which leave it.

How are radiator connections made on this system?

At the top and bottom of the same end.

How should radiators be tapped for use on the overhead system?

Radiators are generally tapped only on one end, at top and bottom, but may be tapped for the flow at the top, and for the return at the bottom of the opposite end.

Should a valve be used on both the flow and return of radiator connections?

One valve only is necessary, and this valve might be placed on either flow or return, but owing to convenience in operating, it is usually placed on the top or flow connection.

How should the risers be run on this system?

They should first feed the highest radiator.

Should air vents be used on radiators on the overhead system?

They should not be used, as this system has the advantage of venting itself at the top of the main riser, where connection is made to the expansion tank.

In the overhead system, what size of pipe should be run from the high point on the system to the expansion tank?

$\frac{3}{4}$ -inch pipe on small work, and 1-inch on large work should be used.

Why is circulation stronger on the overhead system?

The higher the system is run, the greater will be the weight of water and the greater will be its help to the circulation. On some buildings the weight of water is sufficient to heat radiators in the basement below the bottom of the boiler.

What are some of the advantages of the overhead system of hot water heating?

The main supply pipe will supply a greater amount of radiation than it will in a system where cellar piping is used. In this system the air is taken care of automatically, without the aid of air valves, and as stated above, the circulation is stronger, and takes place with less loss of heat than in other hot water systems.

CHAPTER XIX

THE REGULAR SYSTEM OF HOT WATER HEATING

Describe the piping for the regular hot water heating system.

The main flow pipe rises above the boiler to such height that there will be sufficient space between the top of it and the extreme end of the system to allow a proper pitch to the end of the piping.

This main is run in the most convenient manner possible, supplying the various branches or risers to radiators, and being reduced in size as this is done, the return being run the same size as the flow.

How should the piping of this system be run?

The flow and return pipes should be run parallel.

Should the main run full size throughout?

It should not run full size, but should reduce as branches are taken off.

What regulates size of pipes for mains and branches?

Sizes are based on valve area of radiators served. The area of the main flow pipe should never be less than the sum of the areas of all radiator valves which it has to supply.

What size should the main be at the point where the last radiator is connected?

It should be one or two sizes larger than the riser supplying the radiator, two sizes being preferable.

When the main flow pipe divides into two lines running in opposite directions, what kind of fitting should be used?

A double elbow should be used. This fitting divides the flow evenly, with the least possible friction.

How should the return main be run?

The return main should follow the direction of the flow, and is generally run side by side with it, at a distance of eight or ten inches. At the boiler the return drops vertically into the return opening of the boiler.

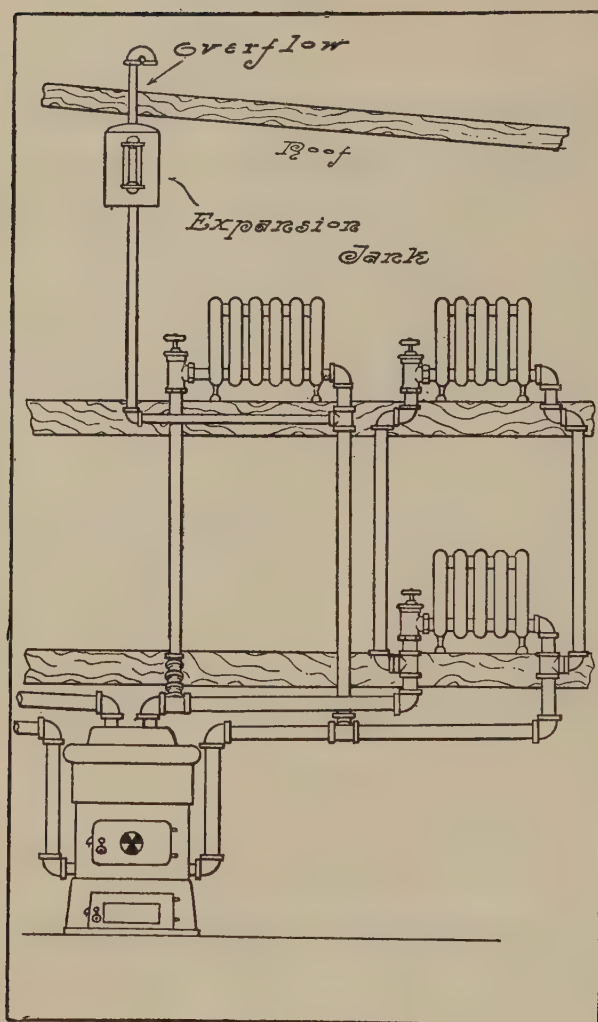


Fig. 22—Two-Pipe System of Hot Water Heating

What should be the size of branch returns in this system?

They should be the same size as branch flow pipes.

How should the expansion tank be connected on this system?

The expansion tank should be placed at a point at least three feet above the top radiator, the connection to it being made from the bottom of the tank to the nearest return riser.

What should be the size of the expansion tank connection?

This depends on the size of the system. A small system will require not larger than $\frac{3}{4}$ inch pipe, while larger systems will require larger sizes.

CHAPTER XX

THE EXPANSION TANK

What is the purpose of the expansion tank?

At its boiling point, water fills a space about 5 per cent. greater in volume than at its densest point, when cold. When cold, the water must fill the entire system. Therefore provision must be made to take care of this extra volume when the water is at the boiling point.

The expansion tank is provided for this purpose on all hot water heating systems.

How should the expansion tank be located?

In a warm room, to prevent freezing.

Where should the overflow from the expansion tank be carried?

The overflow from the expansion tank should be carried through the roof, and on the end of the pipe a return bend or two ells and nipple should be placed, in order that water may not run down the side of the pipe.

Why is the running of the overflow pipe into the basement or into an open fixture not advisable?

For the reason that the pipe in filling with the overflow from the tank might produce syphonage, this action under proper conditions being liable to drain nearly all the radiation on the upper floors.

What additional objection is there to running the overflow from the expansion tank into such a fixture as the water closet tank in the bath room?

The additional objection is that in the event of the water boiling in the system, the room would be liable to fill with steam.

Should a valve ever be used on the expansion pipe?

Never, as it cuts off the use of the tank, which should always be in readiness to perform its part of the work.

How is the size of the expansion tank determined?

It should hold from 1-20 to 1-30 of the amount of water contained in the entire system.

Why should it hold this amount?

For the reason that when at the boiling point, the water in the system will occupy a considerably larger space than when cold.

SIZE OF EXPANSION TANKS FOR DIFFERENT AMOUNTS OF RADIATION

300 square feet Radiation.....	10 gallons
500 square feet Radiation.....	15 gallons
700 square feet Radiation.....	20 gallons
950 square feet Radiation.....	26 gallons
1300 square feet Radiation.....	32 gallons
2000 square feet Radiation.....	42 gallons
3000 square feet Radiation.....	66 gallons
5000 square feet Radiation.....	82 gallons
6000 square feet Radiation.....	100 gallons

How can the capacity of a cylindrical expansion tank be determined?

Multiply the square of the radius of the tank in inches by 3.1416, then multiply this amount by the length of the tank in inches. Divide this result by 231, the number of cubic inches in a gallon. The final result is the capacity of the tank in gallons.

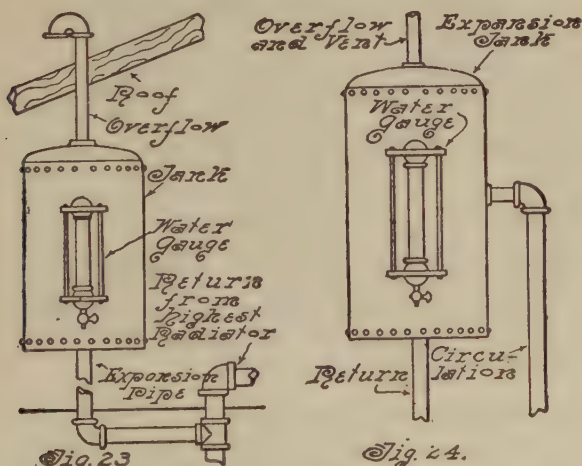


Fig. 23
Correction of Expansion Tanks.

Fig. 24.

CHAPTER XXI

INSULATION OR COVERING OF PIPING

What is the purpose of pipe covering?

The radiation of heat from radiators is the means whereby the rooms of a house are warmed. In the same way, heat is radiated from pipes and heating apparatus at points where heat is not desired, radiation of this kind representing a distinct loss. Much of this loss can be overcome by enclosing pipe in exposed places with pipe covering.

What kinds of materials are used in making pipe covering?

Materials which are poor conductors of heat are used for this purpose, such as cork, asbestos, etc.

TABLE OF NON-CONDUCTING MATERIALS

Substance	Relative Value
Loose Wool	3.35
Feathers	1.10
Felt	1.00
Charcoal (cork)	.87
Silicate Cotton (slag wool)....	.85
Straw Rope (loose).....	.75
Cork	.71
Sawdust	.68
Wood	.50
Asbestos	.50

In the foregoing, felt is taken as the unit.

Describe the making of pipe covering.

The materials used are ground and pressed into the proper shape. Pipe covering is made in three-foot lengths and split lengthwise in halves, to allow it to be put on over the pipe. On the outside of these lengths muslin is glued, this being done to improve the appearance of the covering.

What is "air-cell" pipe covering?

Confined air has been found to be a good non-conductor of heat, and this fact has been made use of in the manufacture of pipe covering of corrugated asbestos paper.

What is the saving in fuel when the piping of a heating plant is covered?

There is a great variance as to the relative efficiency of various forms of covering, but almost any covering of merit will effect a saving of at least 10 per cent. in fuel, while some of the best grades will save nearly 30 per cent. It will thus be seen that money expended for pipe covering becomes a good investment.

To show the saving that is made possible in the use of pipe covering, the following tables from the catalog of one of the foremost makers of pipe covering are taken.

SAVING IN FUEL EFFECTED BY THE USE OF
"ASBESTOCEL" PIPE COVERING

When applied to Low Pressure Steam
Heating Pipes

Pipe Size, In.	Coal saved per foot of pipe per year with 3-ply	Coal saved per foot of pipe per year with 4-ply
1	34.7 lbs.	37.3 lbs.
1¼	45.6 lbs.	48.8 lbs.
1½	53.1 lbs.	56.7 lbs.
2	68.2 lbs.	72.7 lbs.
2½	90.2 lbs.	96.2 lbs.
3	103.7 lbs.	110.6 lbs.
3½	119.6 lbs.	127.3 lbs.
4	135.4 lbs.	144.3 lbs.
6	203.3 lbs.	216.1 lbs.
8	266.7 lbs.	283.4 lbs.

When applied to Hot Water Heating
Pipes

Pipe Size, In.	Coal saved per foot of pipe per year with 3-ply	Coal saved per foot of pipe per year with 4-ply
1	19.3 lbs.	20.8 lbs.
1¼	25.5 lbs.	27.5 lbs.
1½	30.0 lbs.	32.3 lbs.
2	38.5 lbs.	41.4 lbs.
2½	47.5 lbs.	51.1 lbs.
3	59.1 lbs.	63.3 lbs.
3½	68.0 lbs.	72.9 lbs.
4	77.3 lbs.	82.9 lbs.
6	115.9 lbs.	123.9 lbs.
8	152.6 lbs.	163.1 lbs.

How may loss of heat from boilers and other heating apparatus be saved?

By covering them with some insulating cement made for this purpose. The cement is mixed with water and put on with a

trowel. The following table taken from a manufacturer's catalog will give some idea of the saving that may be effected by covering boilers in this way:—

When applied to Low Pressure Steam Boiler

Coal saved per year per sq. ft. of boiler surface if 1 in. thickness of cement is applied.	Coal saved per year per sq. ft. of boiler surface if 2 in. thickness of cement is applied.
150 lbs.	180 lbs.

When applied to Hot Water Heating Boilers

Coal saved per year per sq. ft. of boiler surface if 1 in. thickness of cement is applied.	Coal saved per year per sq. ft. of boiler surface if 2 in. thickness of cement is applied.
64 lbs.	79 lbs.

The figures in the tables are conservative, as they are based on steam temperature of 212 degrees Fahrenheit in pipes, 16 hours per day, and in boilers all day, during a heating season of 210 days. The figures for hot water heating systems are based on average hot water temperature of 130 degrees Fahrenheit, during a heating season of 210 days; average boiler temperature 10 degrees above average temperature of supply and return pipes.

What result does the use of pipe covering and boiler covering have on the size of boiler required?

Frequently a smaller boiler may be used when the piping is covered, and the difference in cost between the small boiler and the boiler required for the work with the pipe uncovered, will partially pay for the pipe covering.

CHAPTER XXII

VENTILATION

What is the importance of ventilation?

Ventilation is a very important matter in heating. All living rooms should be well ventilated, and the larger the number of occupants the room contains, the greater will be the necessary amount of ventilation.

What may be said of the natural ventilation of houses?

In the average house, sufficient ventilation is obtained from the fresh air entering the rooms through the windows and walls, for the ordinary occupancy of the rooms.

How much fresh air is necessary to one person per hour?

Under ordinary conditions, an adult requires about 1000 cubic feet of air per hour.

What are some of the principal causes of the vitiation of air in a room?

The principal cause is the respiration of the occupants of the room. Moisture and gases arising from the person also tend to make the air foul. Lighting, heating, etc., are other causes.

How is the atmosphere of a room changed?

To some extent by diffusion, but most thoroughly and acceptably by the entrance through registers provided for the purpose, of fresh air that has been warmed, and by the outward passage through ventilating flues, of the impure air.

How should a foul air duct enter a room?

Near the floor. The open fireplace furnishes an excellent means of ventilating a room.

Why should this duct be so located?

The poisonous gases and foul air, are heavier than the purer air, and therefore settle to the bottom of the room. By drawing the coldest and therefore heaviest air, which is at the bottom, the warmer air at the upper part of the room settles to fill this

space, thus creating a circulation, and making the heating more effective. This is what might be termed natural ventilation.

What other method of ventilating is used?

Ventilation is sometimes obtained by artificial means, as with fans.

What form of ventilation is most satisfactory for residences?

Natural ventilation is always more satisfactory for residence heating than artificial ventilation.

Which form of ventilation is most satisfactory for a school house, theatre, or public building?

Artificial ventilation by means of fans or otherwise, is best adapted to this class of work, as the amount of fresh air admitted to the rooms can be regulated according to the necessary requirements of the occupants.

What system of heating provides also a system of ventilation?

The system of heating by indirect radiation provides ventilation.

At what rate should the air in dwellings be moved?

When the temperature is at 60 or 70 degrees, it may have a speed of $2\frac{1}{2}$ to $3\frac{1}{2}$ feet per second, but should never move at a higher rate than 5 feet per second.

CHAPTER XXIII

VACUUM AND VAPOR HEATING

But little more than a score of years ago, vacuum and vapor heating was hardly known to the steam fitting trade, except as it was used on some of the larger office and public buildings of the country. Today vacuum and vapor heating are recognized as distinctive systems for heating all classes of buildings, small and large.

In the installation of a steam heating job the steam fitter has had to contend with an arch enemy, air, which when present in a heating system, destroys the full value of it as a heating agent. Steam and air being of different density will not mix. For this reason it has been customary to place air valves of various kinds and forms on each unit of radiation, coil or radiator, and in this manner endeavor to relieve the system of accumulated air.

Vapor and vacuum heating are methods of circulating steam above or below atmospheric pressure, without the destroying agency of air, as all air is removed from the system as fast as it collects. The following pages have to do with the various factors and appliances now used on the several systems of vapor and vacuum heating.

What is a vacuum?

Elsewhere in this book we have stated that a vacuum is a portion of space from which the air has been entirely exhausted. Webster defines the word "vacuum" as an empty space—that is to say, a space absolutely empty or void of matter.

Is the space in an empty bottle or other vessel under a vacuum?

No,—the vessel may be empty of visible contents such as a liquid, but the space is immediately refilled with an invisible fluid, a vaporous gas called air.

How can a vacuum be produced and maintained?

By exhausting all air from the interior of a vessel either by expansion of heat or steam, or by mechanical devices, and afterward closing or sealing the inlet of the vessel against the return of the air,—or as we may say, against the pressure of the atmosphere.

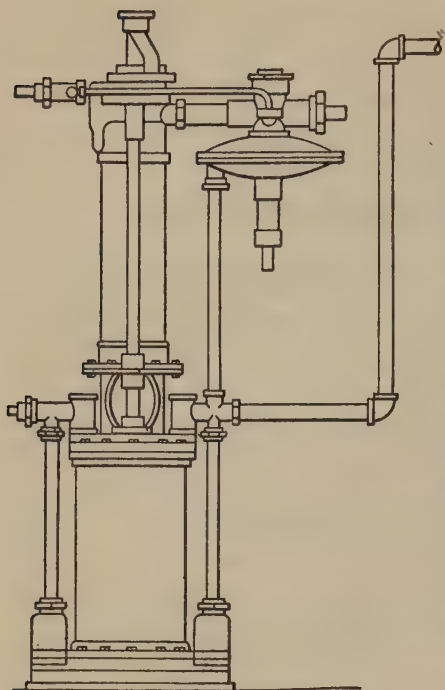


Fig. 0—"Reliable" Vacuum Pump
Used on Small Systems

What is the pressure of the atmosphere?

Under "Theory" we have stated that the pressure exerted by the atmosphere upon the earth's surface is about fifteen pounds per square inch at sea level. The earth is surrounded to the height of several miles with a belt of elastic gas or atmosphere. This atmosphere contains more or less moisture, and owing to its weight the pressure of it upon the earth at sea level, is as before stated, about fifteen pounds per square inch, or to be exact, 14.7 pounds, the air at sea level being more dense than that at a higher altitude. Atmospheric pressure then, is simply the weight of the air.

What relation has this fact to a heating apparatus?

All ordinary forms of heating apparatus are open to the atmosphere through the air valves or otherwise. Owing to the atmospheric pressure of 14.7 pounds upon the water in the heating system, the water cannot boil until a temperature of 212 degrees has been reached, when it is possible to make steam. With the pressure of the atmosphere entirely removed from the surface of the water in the system, it is possible to boil the water and obtain steam at 98 degrees temperature. In a steam heating apparatus a large share of the fuel used is consumed in the effort to drive the air from the system against the pressure of the atmosphere, in order that the steam may circulate through the piping and radiators of the heating system.

Is a vacuum heating system more economical in the use of fuel than a steam system?

Yes, for the reason above stated, and for the further reason that all air being removed from the system each square foot of surface in a radiator or coil is available for heating.

Is not this true of a steam heating apparatus?

No, for with a regular system of steam heating, the air in the radiators and coils is never entirely removed.

Why is this so?

The steam entering a radiator or coil, frequently reaches the air valve, and by expansion closes it before the air is entirely exhausted.

Is vacuum heating quicker in action than steam?

Yes. The velocity of the steam in an ordinary job depends upon the pressure on the system, and may be anywhere from 25 to 150 feet per second, while the flow of steam in a vacuum is said to attain a velocity of 1,550 feet per second.

How is a vacuum on a heating job produced?

On large installations it is usual to employ a vacuum pump, which pumps all water of condensation and all air from the system, maintaining a constant vacuum. On small installations many types of apparatus are used. One system (Bishop-Babcock-Becker) employs a small hydraulic pump, (See Fig. 1) which is automatic in its operation, and will create and maintain any desired vacuum.

Is it necessary to employ mechanical means to produce a vacuum on a heating apparatus?

No. Most of the vacuum systems for small operations depend upon the condensation of steam to produce a vacuum on the job.

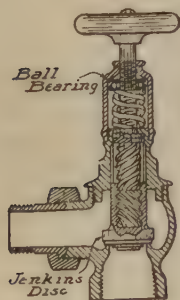


Fig. 1 — Packless Radiator Valve

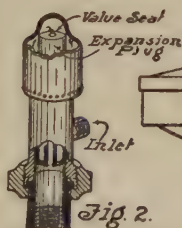


Fig. 2.

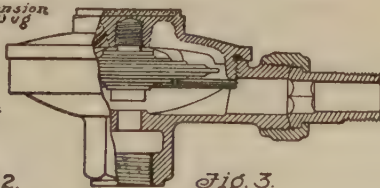


Fig. 3.

Fig. 2—Air Valve for Trane System

Fig. 3—Radiator Trap for Dunham System

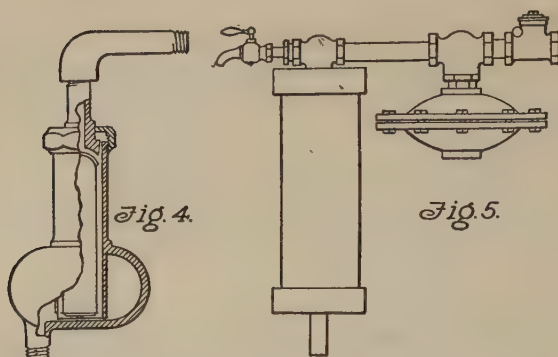


Fig. 4—Retainer Valve for K. M. C. System

Fig. 5—Air Trap for Moline System

How is this accomplished?

A cubic inch of water turned into steam occupies in this gaseous form about 1,700 cubic inches, or stated in another way, a cubic inch of water will make 1700 cubic inches of steam. Therefore when this steam is condensed, it occupied only one-sixteenth hundred and ninety-ninth, (1-1699) of the space it occupied as steam, and if, after a radiator is filled with steam, no air leaks in, this space will be void of matter after the steam has condensed, or in other words, will be under a vacuum.

What then, is necessary to hold this vacuum?

First of all, an air tight job of piping, all valves of the packless variety, or with carefully packed stuffing boxes, a tight fitting safety valve, and tight boiler trimmings.

Fig. 1 shows one type of packless radiator valve. Note the spring holding stem firmly in place.

How is the air removed from the apparatus?

Through special types of air valves on the radiators or coils, or through special appliances on the return of radiators. The Trane system makes use of an air valve as illustrated by Fig. 2. It is of the expansion post type, with union drip connection. The Dunham system uses a form of trap called the Dunham radiator trap, Fig. 3. The disc within the trap is hollow, and contains a volatile liquid which vaporizes when surrounded with steam, forming an internal pressure within the disc, expanding it and closing the trap. When water and air surround the disc, the liquid is condensed, and the disc contracts and opens the trap, allowing the water and air to discharge into the return line.

The Bishop-Babcock-Becker system makes use of an air

valve with drip connection. Any good air valve of the expansion post variety will prove satisfactory.

The K-M-C system uses a special air valve called a retainer valve. Fig. 4 shows its construction.

The Moline system uses no air valves on the radiators, but exhausts all air through an air trap, Fig. 5, which is located in the basement above the air line.

Must special devices be used for taking care of the air on all vacuum jobs?

Yes. Those described are typical of all others, each system making use of some peculiar or distinct type of valve or appliance.

Is a vacuum job piped similarly to an ordinary job of steam heating?

Yes. As a rule any good job of steam piping will prove satisfactory for vacuum heating.

Are they one-pipe or two-pipe systems?

Those systems which exhaust the air through an air valve may be piped either style, but in addition must have an air line main, into which the air pipe from all radiators must connect.

Those systems which use no air valves, must be piped two-pipe, as the air is exhausted through the return, together with the water of condensation.

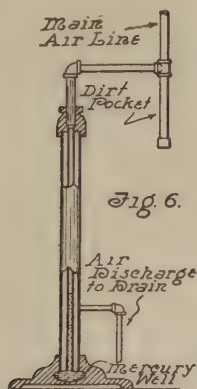


Fig. 6—Mercury Seal Device for Trane System

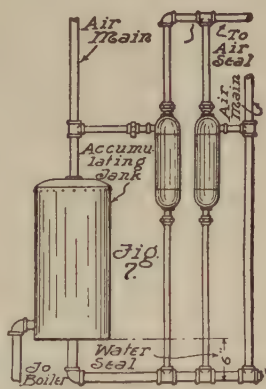


Fig. 7—Connections to Floating Checks for K. M. C. System

Where do the air lines terminate?

Usually at a point near the boiler, where they connect with some device for separating the air from the system.

The Trane system employs a mercury seal device, Fig. 6, which is located near the boiler. It consists of a double tube, dipping into a pot of mercury. The air is exhausted through the mercury, which prevents its return to the system, as the mercury effectually seals the end of the air pipe.

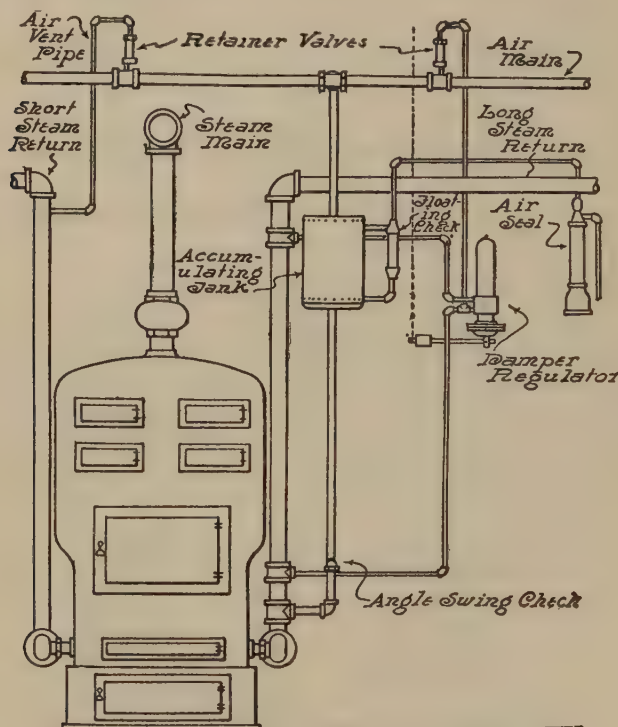


Fig. 8—The "K. M. C." Steam Vacuum System

The K-M-C system makes use of a similar mercury appliance, in addition to which there is a small tank called an accumulating tank, which is partially filled with water, in order to condense any vapor or steam which might enter through the return line. From the tank the air passes through a floating check into the mercury seal device, and thence to the atmosphere. Fig. 7 shows the method.

The general method of piping and connecting the various special appliances for a simple K-M-C system, is shown by Fig. 8.

With the Dunham system the water and air in the return lines pass through swinging check valves, into a small receiving tank, where the air and water are separated, the water passing through check valves into the return of the boiler, the air to the atmosphere through an automatic vacuum valve above the tank. A pipe loop called an equalizing pipe, connects to the top of the tank, and into the top of the boiler, by a special coupling. This pipe extends to a point below the water line of the boiler.

So long as the boiler pressure will not force the water inside the boiler to the top of the loop, there will always be a higher pressure in the boiler than in the tank. Also when the water in the boiler seals the bottom of the equalizing pipe, no steam can get into the tank.

When the water in the boiler is lowered below the bottom of the tube, due to the evaporation of steam, the steam in the boiler enters the tank through the tube, equalizes the pressure between boiler and tank, and allows the accumulated water in the tank to feed into the boiler by gravity. Fig. 9 illustrates the method.

The Bishop-Babcock-Becker system allows the water of condensation to enter the boiler by gravity. The air lines terminate at a cast iron trap called a condenser, first passing through a strainer and check valve. From the condenser the automatic hydraulic pump exhausts the air to the atmosphere. See Fig. 10.

Are the vacuum systems described typical of all vacuum heating systems?

Yes. All of the so-called non-mechanical vacuum systems supply steam to the radiators in the usual manner, by any one of the one-pipe or two-pipe methods. If air valves with drips are employed, the drips are connected into an air line, at the end of which is some form of device for allowing the air to escape to the atmosphere, and sealing the system against its return.

If no air valves are used, the air and return water of condensation both pass through the return lines to the boiler, at which point some device is used to separate the air from the water, and at the same time maintain a seal on the system against the atmosphere or the return of the air. This device allows the air to escape to the atmosphere, and the water of condensation to return to the boiler.

What is meant by vapor heating?

When a heating system is sealed to the atmosphere, the water in the apparatus will boil at a very low temperature. Before the boiling point is reached, a vapor or mist rises from the surface of the water in the boiler, and by vapor heating is meant the

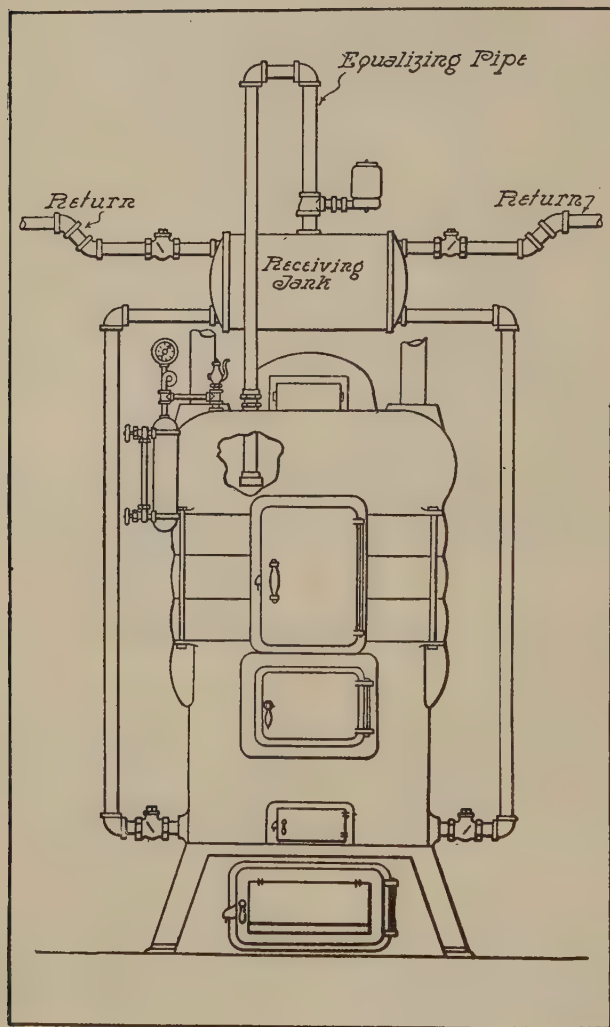


Fig. 9—The Dunham System

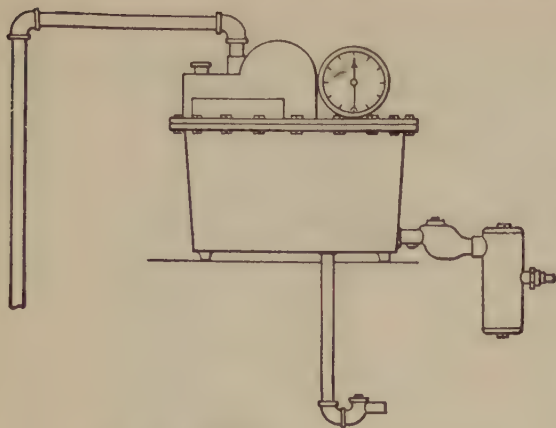


Fig. 10—Condenser for Bishop-Babcock-Becker System

circulating of this vapor through the radiators or coils, without any considerable pressure on the system.

Do vapor systems heat entirely without steam pressure?

No. Some vapor systems are so installed that either vapor or steam may be used, thus giving a range of temperature from about

90 degrees to 240 degrees, 240 degrees being steam at 10 pounds pressure.

How is a vapor job piped?

Practically the same as an air or return line vacuum system. The hot water type of radiator is employed, and the flow is connected into the top of one end, the air and water escaping at the bottom of the opposite end of the radiator shown in Fig. 11.

Special forms of valves are used, whereby the amount of vapor or steam entering a radiator may be controlled or graduated. Fig. 12 shows the graduated valve employed by the Kriebel system. The Broomell system uses a valve with several holes or ports through the disc, as illustrated by Fig. 13, and one or more of these ports are opened at a time.

What are the advantages of using such valves and connecting to the top of the radiator?

Only sufficient steam or vapor is admitted to a radiator to heat to the required temperature. Thus the radiator is heated from the top down,—one-quarter, one-half, three-quarters, or its entire surface as desired.

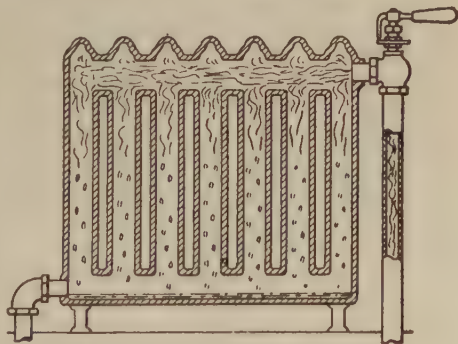
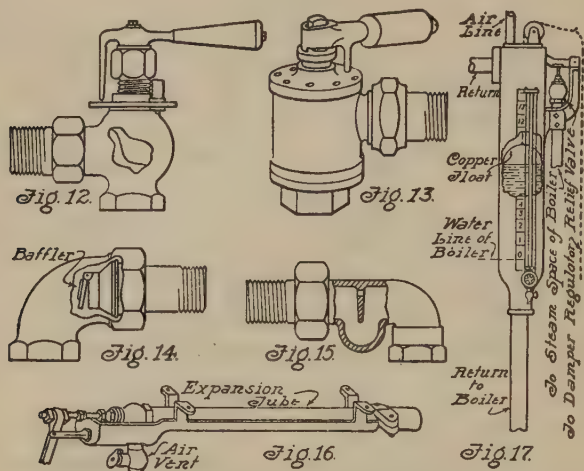


Fig. 11—Method of Supplying Vapor to Radiator

What form of device is used on the return end of the radiator?

The Kriebel system makes use of a union elbow with a baffle as shown by Fig. 14. The Broomell system employs a union elbow having a trap or water seal, as illustrated by Fig. 15, and other systems make use of similar appliances.



Special Valves and Devices for Controlling Amount of Vapor or Steam

What other special features or fittings are used on a vapor system?

The method of expelling the air on a vapor system is not unlike the method used for vacuum heating, and calls for the use of some special fixture for the purpose. Fig. 16 shows the vapor-vacuum controller, a device used on the Kriebel system. This is located above the boiler, and through it the air is expelled and the system sealed or controlled.

The Broomell system makes use of a combined receiver, draft-regulator and relief valve, as shown by Fig. 17. The air line connects into the top, and the return line into the side at a point near the top. The figures shown on the gauge, register ounces of pressure. When there is no pressure on the job the water in the receiver stands at 0, the zero mark, which is the water line of the water in the boiler.

When the water is expanded by heat, it rises in the receiver, raising the copper float shown. A chain attached to the top of the float connects with the dampers of the heater, which are open when the float is at zero mark. As the heat increases, the float rises, and the dampers start to close. If the pressure continues

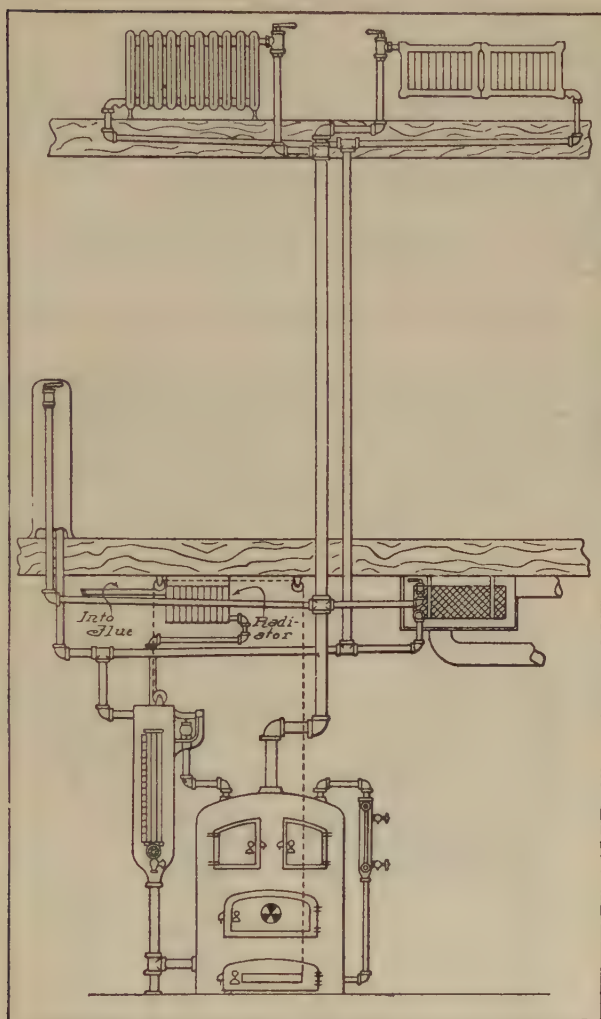


Fig. 18—The Broomell Vapor System

to increase after the drafts of the heater are closed, the float will finally lift the lever operating the relief valve. The appliance may be set to close the drafts of the heater at any point between zero and full pressure.

This system also requires a condensing radiator, usually composed of several sections of indirect radiation, which is hung from the ceiling of the basement, above the piping system. This fixture is employed to condense any vapor which may enter the return line, so that air and water only enter the receiver.

In Fig. 18 are shown complete connections for the Broomell vapor system.

The method of operation of the Kriebel system is clearly shown by Fig. 19.

Are vacuum and vapor systems dependable and positive in operation?

Yes, they are dependable, positive, safe and economical. The time is rapidly approaching when these systems will entirely supersede steam heating, as they not only provide for a greater range of temperatures, but they also are much more economical in operation, and their cost but little more than cost of a steam apparatus, and no trouble from air in the system, or from leaky air valves.

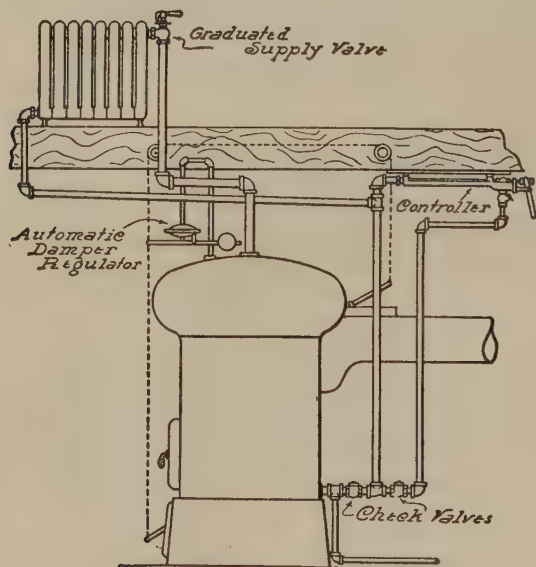


Fig. 19—The Kriebel System

CHAPTER XXIV

INDIRECT HEATING OF HOT WATER FOR DOMESTIC USE

What two methods of heating water for domestic use are in common use?

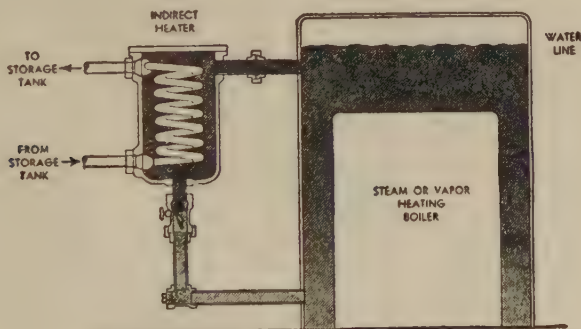
These methods are known as direct and indirect hot water heating.

Explain the difference between direct and indirect heating of domestic water supply.

In the direct method, the water is heated by direct contact with the source of heat, as in the case of the common type of gas water heater. In the use of the indirect water heater, water flowing in the domestic supply system is heated by the transfer of heat from steam or hot water flowing in a separate circuit connected with the heating boiler.

Describe the construction and operation of an indirect heater.

The general idea of such a heater, with its connections to the heating boiler, is shown in Figs. 1 and 2. In this type of heater, a copper coil sets inside a tight casing. The domestic supply to



Reproduced by permission from the B & G Handbook

Fig. 1—Illustrating the principle on which the Indirect Water Heater operates

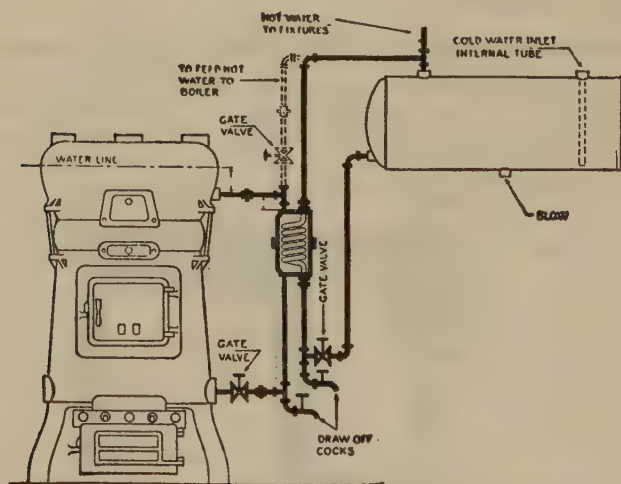
be heated, passes through the coil and is heated by the hot water or steam from the heating boiler, flowing through the heater. It is the hot water or steam that is in contact with the copper coil that does the heating.

In what types of heating system may the indirect heater be used?

It may be used in connection with all types of steam and hot water and vapor heating boilers. Typical applications of the indirect heater are to be seen in Figs. 3, 4, 5 and 6.

How should indirect water heaters be connected to steam and vapor heating boilers?

Generally it is considered that they should be connected below the water line of the boiler, for best results. The heaters shown in Figs. 1 and 2 are so connected. When used in connection with the steam plant of buildings such as institutions, factories, etc., where the pressure of steam remains constant, indirect heaters can be connected above the water line, in which case the heating of the water is done by steam. This is a very satisfactory method.



Reproduced by permission of Davis Engineering Corporation

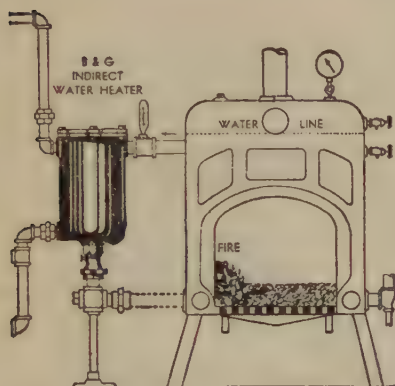
Fig. 2—A common type of Indirect Water Heater, for use in dwellings such as residences, for two, three and four family houses, etc.

How does use of the indirect heater enter into "year around" service?

In answering this question, we quote (with permission) from the B & G Handbook, as follows:

"Indirect water heaters will supply hot water in summer as well as winter, from either steam or hot water boilers fired with any fuel.

On automatically fired steam or vapor heating boilers it is necessary to install a B & G or other suitable hot water control below the water line to avoid getting boiler temperatures above the steaming point during times when heat is not required in the radiators. This control, when set to maintain boiler water below the steaming point, and when properly sized heater is installed, will deliver abundant hot water at all times.

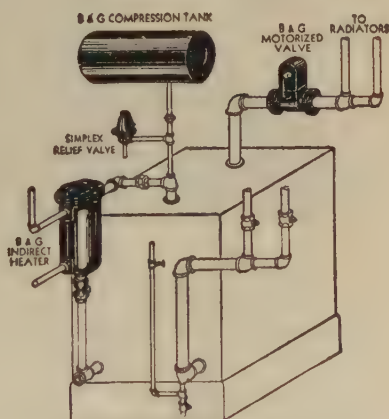


*Reproduced by permission from the
B & G Handbook*

Fig. 3—

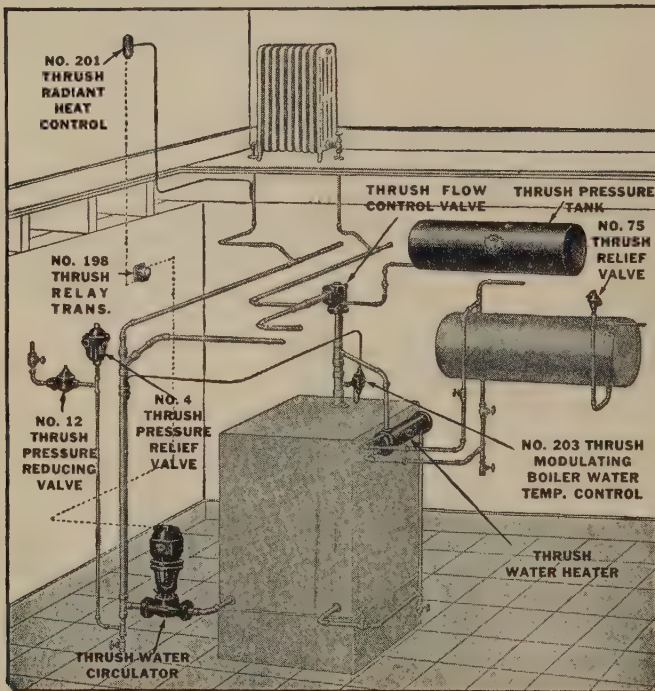
Indirect Water Heater connected to hand-fired boiler. Illustration shows recommended method of firing for summer operation

Indirect Water Heater connected to gravity hot water heating system, with motorized valve used to permit summer operation



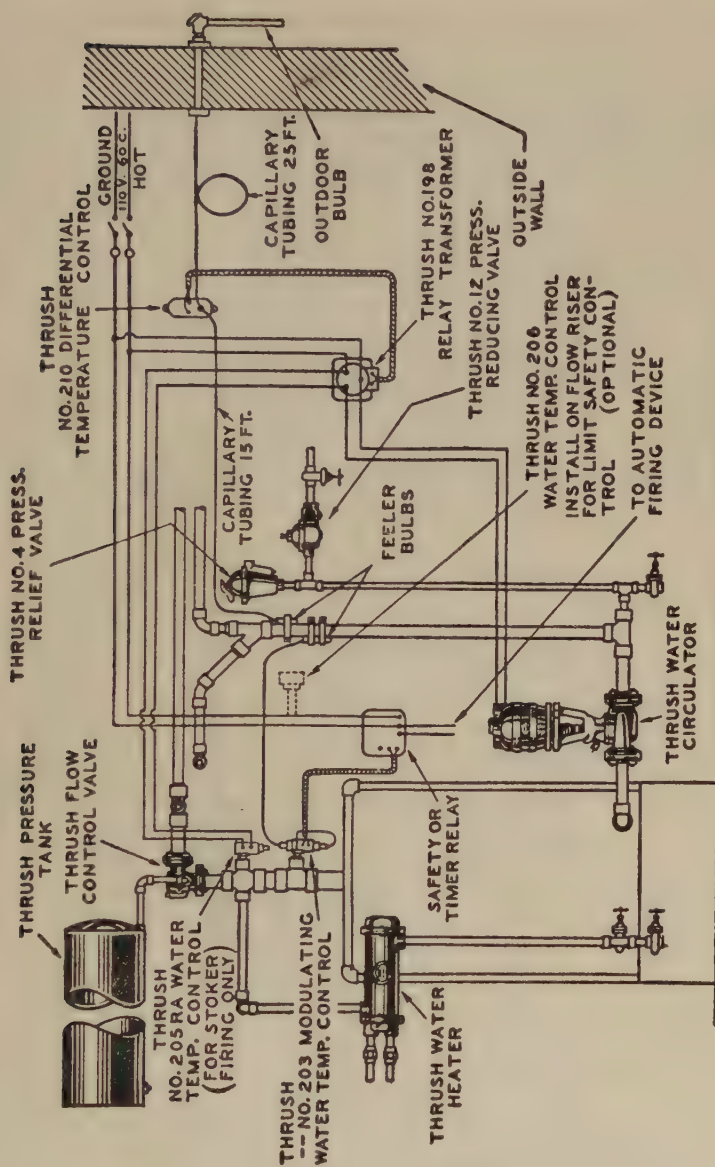
*Reproduced by permission from the
B & G Handbook*

For hand-fired coal burning steam or vapor boilers, during summer operation, only a small fire is required along one side of the boiler. Pack the rest of the grate a few inches deep with ashes. Experiment with the size of fire required to maintain the boiler water temperature between 180° and 200° . Once a day break up the red hot coals and push them over to the side of the boiler. For most economical operation never allow the fire to get into the center of the boiler. When adding fresh coal, do not completely cover the red coals but leave some exposed to burn the coal gases.



Reproduced by permission of H. A. Thrush & Co.

Fig. 5—A horizontal type of Indirect Water Heater shown in connection with a forced hot water circulation system of heating. Full information on this system of heating found in Chapter XXXII



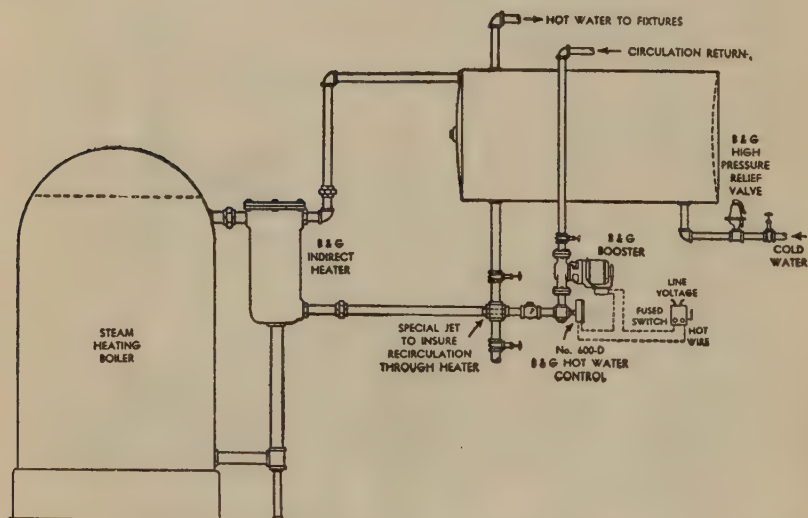
Reproduced by permission of H. A. Thrush & Co.

Fig. 6—Indirect Water Heater used on forced circulating flow control system, with differential temperature control

On a forced circulation hot water boiler, the temperature of the boiler water is similarly kept within certain limits. Circulation to the radiators is prevented by a flo-control valve, installed in the supply main, which remains closed, except when the room thermostat calls for heat and the booster pump is running, or when the boiler is inadvertently overfired.

Even gravity hot water systems can have the benefits of indirect water heating. In this system, a motorized valve is installed in the supply main to prevent circulation to radiators in summer. The valve is electrically controlled to open only when the room thermostat calls for heat, thus permitting the use of an indirect heater to furnish a year around supply of hot water. Or, a gravity system can be brought completely up-to-date from both a comfort and economy standpoint by installing a B & G indirect heater, B & G booster, and B & G flo-control valve. This equipment converts it into a forced circulation system."

Further information on this general subject can be gained by reference to Figs. 7, 8 and 9, and to Chapter XXXII.

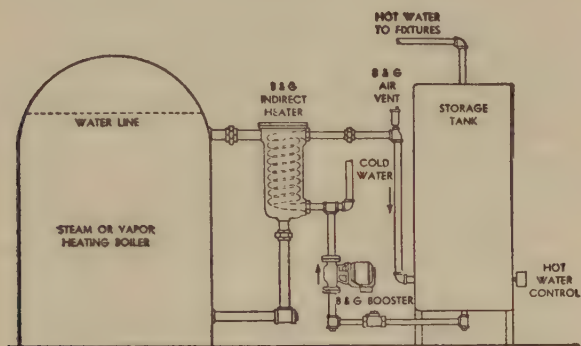


Reproduced by permission from the B & G Handbook

Fig. 7—Indirect Water Heater used in connection with a forced hot water circulation system, in which a circulator is used to circulate hot water to fixtures

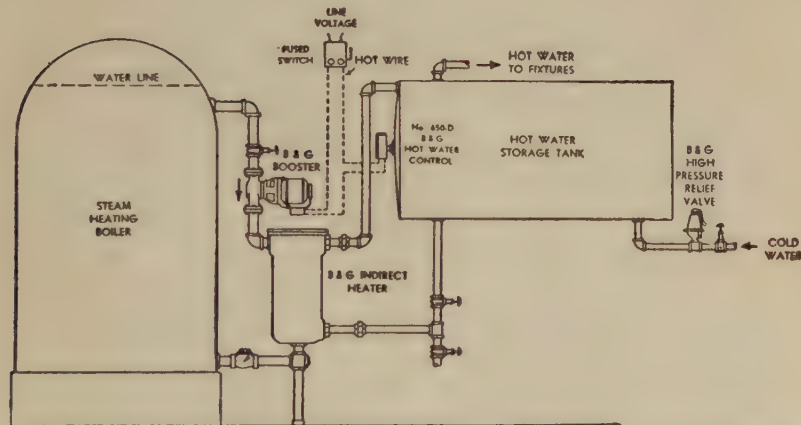
For what other purposes besides heating domestic water, are indirect water heaters used?

They are used for many other purposes, including the heating of swimming pools, the warming of tanks on sprinkler systems, to keep them from freezing, for heating radiation, for hospital use in connection with sterilizing apparatus, for various special industrial purposes, etc.



Reproduced by permission from the B & G Handbook

Fig. 8—A circulator forcing the circulation of hot water between an Indirect Water Heater and a vertical hot water storage tank



Reproduced by permission from the B & G Handbook

Fig. 9—A circulator used to circulate hot water from the boiler through a low Indirect Water Heater

In what two types are indirect water heaters made?

They are made either vertical or horizontal.

In what other three ways may indirect heaters be classified?

These heaters are made with a single coil, with a double coil, or as horizontal tube heaters.

What is the range of service for indirect water heaters?

In the B & G line of indirect heaters, which is typical, the range is based on the number of gallons of domestic water flowing through the coil, which can be heated in three hours, from 40 degrees to 140 degrees. This naturally depends on the temperature of the water in the boiler. The B & G table of capacities is as follows:—

CAPACITIES IN GALLONS IN THREE HOURS
Heated from 40° to 140°

TYPE OF HEATER	Boiler Water at 212°	Boiler Water at 200°	Boiler Water at 180°	Steam of 1 lb. Gauge Pressure
SINGLE COIL HEATERS	30	25	18	60
	40	33	24	80
	52	42	31	104
	70	57	43	140
	90	74	55	180
	100	82	61	200
	120	98	73	240
DOUBLE COIL HEATERS	150	123	92	300
	160	131	98	320
	200	164	122	400
	300	246	183	600
	400	328	244	800
	500	410	305	1000
	600	492	366	1200
HORI- ZONTAL TUBE HEATERS	800	656	488	1600
	1000	820	610	2000
	1200	984	732	2400
	1600	1312	976	3200
	2000	1640	1220	4000
	2500	2050	1525	5000
	3000	2460	1830	6000

CHAPTER XXV

PIPE FITTING IN CONNECTION WITH REFRIGERATING PLANTS

Is there much work for the steamfitter, in connection with refrigeration?

There is much work in connection with refrigerating plants, whether large or small, which the steamfitter is qualified to do. This work is in his line, and he will find that it can be made a paying specialty. There are certain things peculiar to this work, however, which he should know, and the writer has thought it a wise plan to add a short chapter on the subject, taking up briefly those features which seem to be of special practical importance, and giving concisely a general idea of the apparatus of a refrigerating plant.

What are the special features of a refrigerating plant?

There are six distinct features in mechanical refrigeration—the compressor, condenser, receiver, expansion valve, expansion coils, and the gas used in the system.

What is the purpose of the compressor, and how is it driven?

The compressor may be any form or variety of pump suitable for pumping the gas to be used. Some are made with inclosed crank cases, with a stuffing box on the shaft, while others have stuffing boxes on each cylinder, similar to a steam engine. They are generally driven either by steam or electricity, and sometimes by a gas engine.

What is the purpose of the condenser and what is its construction?

The condenser is a series of pipes arranged in columns, through which the gas is pumped by the compressor, and condensed into liquid form. The condenser is sometimes cooled by a thin sheet of water falling down over the pipes. Such a condenser is known as an atmospheric condenser. Condensers are also made of two pipes, one inside the other, suitable fittings being provided at the ends, so that the cooling water may flow through the inner pipe, while the gas passes through the space

between the two pipes. This is a double-pipe condenser, and is the most common form.

What is the receiver and what are its connections?

The receiver is nothing more than a steel cylinder or drum, capable of standing the highest pressures used in each particular system. It usually has three connections,—an inlet for the liquid from the condenser, a drain valve at the bottom, and an outlet for the line going to the expansion valve.

What is the object of the expansion valve?

The expansion valve is a special form of valve with a needle point, and may be operated either by hand or automatically by means of the pressure in the expansion coils. The object of this valve is to make the liquid coming from the receiver expand quickly into a gas.

What is the purpose of the expansion coils?

The expansion coils are pipe coils placed in the compartments or rooms to be cooled. They serve just the opposite purpose of steam coils—that is, they carry cold gas that chills them, and absorb the heat in the compartment or room, while steam coils carry hot gas that gives out heat to the room. Being designed to absorb heat, these coils are naturally placed in the hottest part of the room, near the ceiling.

What kind of gas is necessary in refrigerating work?

Some form of gas must be used that can be easily condensed into a liquid and expanded back into a gas, without being broken up into different substances.

What gases are commonly used in refrigeration?

There are three different gases commonly in use, sulphur dioxide, carbon dioxide, and ammonia. The last is by far the most commonly used, over ninety per cent. of refrigerating plants employing it. All of these gases are deadly in the open air, and therefore should be handled carefully.

Give briefly a general description of the refrigerating process.

The refrigerating process is as follows: The liquid in the receiver is fed through a small line to the expansion valve, quickly expanding into a gas and becoming cold. Passing through the expansion coils, it absorbs the heat of the rooms. The compressor pumps it out of the coils into the condenser, where it is condensed into a liquid and runs into the receiver, where it is ready to go through the expansion valve again. Reference to

Fig. 1 will help the reader in following the several steps taken in the process of refrigeration.

What is meant by the high side and low side of a system?

The part of the system between the compressor and expansion valve, including the condenser and receiver is the high side, and the rest is the low side.

What pressures are used in refrigeration?

Pressures in systems where sulphur dioxide is used run from twenty to one hundred pounds, the higher in the high side, and the lower in the expansion coils. With carbon dioxide, pressures run from two hundred to twelve hundred, and with ammonia, from thirty to two hundred and fifty.

What special feature makes the use of special material necessary in refrigeration?

The deadly nature of the gases used determines the material of pipe and fittings. Brass and copper cannot be used because all three gases corrode them. Cast iron fittings cannot be depended upon, for they are liable to be porous. Malleable iron, or drop-forged fittings, are most commonly in use. Drop-forged fittings, however, are liable to bend and stretch when made up on the lines.

What type of valves is required in refrigerating work?

All valves used on this work should have soft seats, to insure complete shutting off when closed. They should also have a back seat and stuffing box. The back seat will keep the gas from leaking when the valve is wide open, and allow the stuffing box around the stem to be repacked without danger. Without the back seat, the whole line would have to be pumped out to repack the valve. The back-seat valve is illustrated in section in Fig. 2.

What joint sealer is best adapted to refrigeration work?

Litharge and glycerine makes the best joint sealer. It sets quickly and firmly, but good litharge must be used that has not been exposed to moisture, for otherwise it will not dry hard and tight.

How should litharge be applied?

When small lines are being run, litharge should not be put onto the fitting threads, but onto the pipe threads. If put onto the fitting threads it is liable to plug the fitting. A good rule is to use no litharge on fitting threads smaller than $\frac{1}{2}$ -inch.

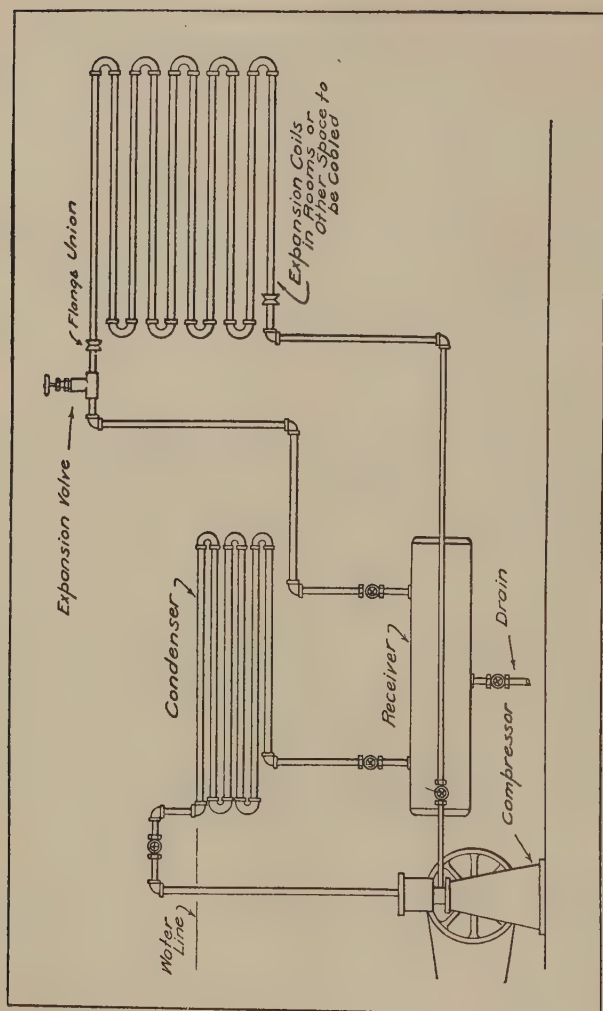


Fig. 1—General Plan of Connections for Refrigerating System

What must be done whenever a joint is broken?

A screwed joint once made up and allowed to set, must be made up again if disturbed, as it will almost surely leak if not so handled.

What kind of pipe should be used in refrigeration?

The best practice in the use of pipe, calls for extra heavy wrought iron pipe up to and including 1½-inch. Above this size full weight will do when sulphur dioxide or ammonia are used. Piping carrying carbon dioxide, where pressures run to 1200 lbs., should be of extra heavy grade in all sizes.

Either steel or wrought iron pipe, with lap-welded joints, may be used in refrigerating plants.

Until within a few years, wrought iron pipe was much superior to steel pipe, the latter rusting rapidly, while wrought iron resisted rusting. During the last few years, however, wrought iron pipe has grown poorer in quality, and steel has improved. The result is that at the present time either steel or wrought iron may be used with equally good results. Some recent tests have even shown steel pipe to be a little better than wrought iron. A few years ago steel pipe joints had the fault of breaking at times, but now hold much better.

Is the use of tested pipe necessary?

Under no circumstances should pipe be used on this work that has not been properly tested.

In testing pipe, air pressure should be applied to each length, and at a pressure well above the highest possible working pressure. If this course is followed, it will help greatly in reducing erecting costs. The extreme working pressures have been given earlier in this chapter, for the three different systems.

How should the air test be applied?

When putting the air test on a system, the pressure should be pumped up slowly. If pumped up rapidly the air may become heated enough to cause an explosion of the oil vapors in the line.

What type of valves and fittings should be used?

Fittings may be either screwed or flanged. Screwed fittings and valves are of course cheaper, and serve just as well, if not better, than flanged fittings, especially in the smaller sizes.

How should flanged joints be sealed?

All flanged joints should be sealed with lead gaskets. Some manufacturers use rubber gaskets, but this is a mistake, as there is always more or less oil in the system, especially when am-

monia is used, which will attack and destroy the rubber. It is not an uncommon thing to have a rubber gasket blown out of a joint. Lead is not harmed by any of the gases, and is soft enough to flow and make a tight joint.

How are reductions in pipe sizes generally made?

Ordinarily reducing fittings are not used in refrigerating work. If a reduction in size must be made, a steel bushing should be used. Malleable bushings will sometimes do, but cannot always be depended upon to make a tight joint.

What are the requirements in the threading of pipe?

Clean threads must be cut on pipe if tight joints are to be obtained. Dies should be ground to suit the kind of pipe on which they are to be used. A die ground for wrought iron pipe will not cut clean threads on steel pipe. In refrigerating work, too great care cannot be given to obtaining properly ground dies.

What are the requirements in supporting the expansion coils?

The supports or hangers for the expansion coils will usually be furnished by the manufacturer of the machine. They must be designed strong enough to support not only the coils themselves, but also the accumulation of ice and snow that will form on them. The writer has seen coils made of 2-inch pipe that have had a coating over 4 inches thick of solid ice their entire length. Therefore, the manufacturer should not be blamed if the supports appear to be needlessly heavy or strong. Coils are usually made of either 1¼-inch or 2-inch pipe, and are figured according to the square feet of their surface.

How should lengths of pipe be connected together?

Flanged unions should be used between lengths of pipe. They make a tighter joint than a coupling, and make it much easier to replace a length of pipe when that becomes necessary.

What are some of the requirements in the use of flanged unions?

A union should always be used between two tees, to allow taking down. Never put a flange and an ell or tee in a line with a close nipple between them, for it will only mean taking them out again and separating them by a longer piece of pipe. When making close connections, no nipples shorter than six inches can be used if proper allowance is made for the flange covers. Do not run a long line with branches and omit to use unions. It may be cheaper to put up, but when the air test is

put on, and a large part of it has to be pulled down to fix a few leaks, the saving in expense is often overcome many times over. Do not forget that you are dealing with a deadly gas, and that the line cannot be put up too well.

What practice is generally followed in the use of flanges?

Oval flanges are used on all sizes up to and including $1\frac{1}{4}$ -inch pipe, such flanges using only two bolts.

Square flanges are used on pipes larger than $1\frac{1}{4}$ -inch, these flanges requiring four bolts.

How should joints be screwed up?

Do not think that the pipe must be screwed into the fitting hard as it can be, for a medium tight joint with clean threads will hold better than one that is pulled up hard.

What course should be followed in opening an old line of pipe?

When an old line has to be opened, be absolutely certain that it is first pumped out. No mistake should be made about this. Then crack a flange a very little on the side away from you to allow any gas that may be present to blow out. Many a fitter has received bad burns because of lack of caution in this matter. If care is exercised, however, and good workmanship obtained, there will be no danger.

How are joints to be tested for leaks?

All joints should be tested with soap suds for the detection of leaks. A very small leak that will hardly show under air pressure, will cause a great deal of trouble when the gas is in the system. It is for this reason that unusual care must be used in getting the line tight. Refrigerating lines **must be absolutely tight**. Ammonia and sulphur gases can be smelled, and will therefore give warning of leaks. Carbon dioxide, however, has no odor, which makes it more dangerous to use, and therefore great care should be exercised in handling it.

What danger is to be guarded against on repairing a double-pipe condenser?

When repairing a double-pipe condenser that is frozen, care must be used to avoid losing gas. If a pipe has frozen and split, as soon as the ice is melted the gas will rush out, under which conditions danger may arise.

One of the sketches shown in Fig. 1 serves to show the special fitting used on the double-pipe condenser.

What are the requirements for insulation or covering for refrigerating lines?

Insulation for refrigerating lines should be carefully selected. It must be waterproof and non-absorbent. With steam pipes the heat keeps the covering dry and in good condition, but in the case of refrigerating lines the pipes are cold, and sweat or become frosted. If the covering is not waterproof it will be a matter of only a few weeks before it will be almost a solid mass of ice, due to the constant condensation of the water in the atmosphere. The best covering is made of ground cork, pressed into form.

How is the pipe covering applied?

The covering is applied as shown in our illustration, Fig. 2, and it will be seen that not only is the pipe itself covered, but the flanges and fittings have to be covered with special covers. The space between the flange cover and the fitting is filled with a special putty.

What allowance should be made for clearance between lines of pipe in refrigeration work?

Clearance must be left between lines of pipe and fittings, for the sectional cork or other covering that will be put on the piping after it has been tested.

The proper provision for clearance between lines of pipe and fittings may be figured from the following tables:

Size of Pipe	Outside Diameter of Covering
$\frac{1}{2}$ inch	4 $\frac{1}{2}$ inches
$\frac{3}{4}$ inch	4 $\frac{3}{4}$ inches
1 inch	5 $\frac{5}{16}$ inches
1 $\frac{1}{4}$ inches	6 $\frac{5}{16}$ inches
1 $\frac{1}{2}$ inches	6 $\frac{3}{8}$ inches
2 inches	7 $\frac{1}{4}$ inches

Size of Pipe	Outside Diameter of Flange Cover
$\frac{1}{2}$ inch	8 inches
$\frac{3}{4}$ inch	9 inches
1 inch	9 $\frac{1}{2}$ inches
1 $\frac{1}{4}$ inches	11 $\frac{1}{4}$ inches
1 $\frac{1}{2}$ inches	12 inches
2 inches	12 $\frac{1}{2}$ inches

Size of Pipe	Minimum Distance between Centers of Lines
$\frac{1}{2}$ inch	$6\frac{1}{2}$ inches
$\frac{3}{4}$ inch	7 inches
1 inch	8 inches
$1\frac{1}{4}$ inches	$8\frac{1}{2}$ inches
$1\frac{1}{2}$ inches	$9\frac{1}{2}$ inches
2 inches	10 inches

Do the precautions given above apply to all systems of refrigeration?

While most of the precautions mentioned, apply to plants using ammonia, most of them apply equally to the other systems.

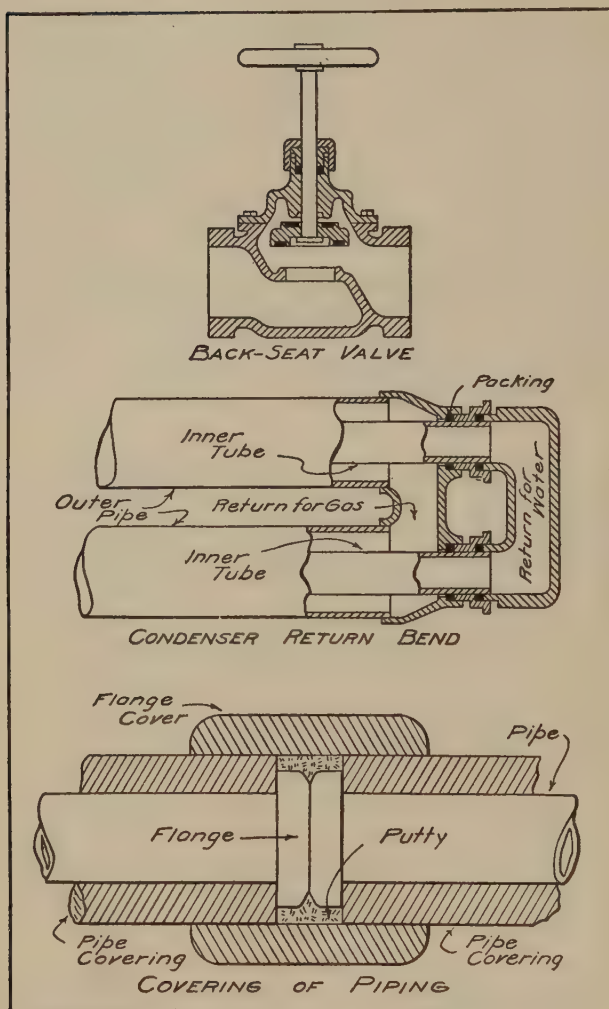


Fig. 2

CHAPTER XXVI

THEORY

What is atmospheric pressure?

It is the pressure exerted by the atmosphere upon one square inch of surface, or in other words, it is the weight of a column of air one square inch in cross section. At the sea level this column of air, that is, the earth's atmosphere, is about 45 miles deep, and exerts a pressure of about 15 pounds per square inch.

Why is atmospheric pressure less at the top of a mountain than at sea level?

For the reason that at the top of an elevation, the depth of the atmosphere is necessarily less than at lower points.

How is the boiling point of water affected by atmospheric pressure?

The temperature at which a liquid boils, rises as the atmospheric pressure increases. Therefore water will boil at a lower temperature at the top of a mountain than at its base.

Explain the action of expansion and contraction.

When heat is applied to a metallic body, the particles of which the body is composed increase in size, and the body itself naturally occupies a larger space than before. This is the action of expansion.

When the body cools, the opposite action takes place, and the body contracts. If heat is applied beyond a certain amount, varying with each metal, expansion becomes so great that the particles will no longer hold together, and the body is transformed into the liquid state. Expansion and contraction apply to many substances besides metals, such as air, water, etc.

How does the expansion of water differ from that of other substances?

As stated above, substances in general continue to expand as long as heat is applied, and contract as long as the heat is lessened. Water is heaviest at 39.2 degrees, and when heated above, or cooled below this point, it expands.

If this were not so, at the freezing point the coldest water would be at the bottom, and the formation of ice would begin at the bottom of rivers and ponds, the entire body of water finally becoming a solid mass of ice.

Does heated air and water rise or fall, and why?

Heated air and water rise because their particles are more expanded, and therefore lighter than the colder particles.

How does this principle find application in heating?

In the circulation of air and water.

What is a vacuum?

A vacuum is a portion of space from which the air has been entirely exhausted.

What is evaporation?

It is the slow passage of a liquid into the form of vapor.

What causes increase the rate of evaporation?

Increase of temperature, increased exposure of surface, and the passage of air currents over the surface.

What is condensation?

Condensation is the passage of a vapor into the liquid state, and is the reverse of evaporation.

What are the laws governing the pressure of liquids?

1—Pressure exerted upon a liquid is transmitted undiminished in all directions, and acts with the same force on all surfaces, and at right angles to those surfaces.

2—The pressure at each level of a liquid is proportional to its depth.

3—With different liquids and the same depth, pressure is proportional to the density of the liquid.

4—The pressure is the same at all points on any given level of a liquid.

What is buoyancy of a liquid?

The pressure of the upper layers of a body of liquid on the lower layers causes the latter to exert an equal reactive upward force. This force is called buoyancy.

Does the pressure of a liquid depend upon the shape of the vessel containing it?

It does not.

What is fluid friction?

In flowing over any surface, for instance the sides of a pipe, a fluid meets with more or less resistance from the surface. This resistance is called friction.

What are the laws which govern the friction of fluids?

1—Friction does not depend in the least on the pressure of the fluid upon the surface over which it is flowing.

2—Friction is proportional to the area of the surface.

3—At a low velocity (not more than one inch per second for water) friction increases with the velocity of the liquid.

4—Friction increases with the roughness of the surface.

5—Friction increases with the density of the liquid.

Is the friction of water greater in small or in large pipes, and why?

Friction is greater comparatively, in small pipes, for a greater proportion of the water comes in contact with the sides of the pipe than in the case of the large pipe. For this reason mains on heating apparatus should be generous in size.

How do the compressibility of air and water compare?

Air is extremely compressible, while water is almost incompressible.

Of what is water composed, and what are the proportions?

Water is composed of two parts of hydrogen, and one part of oxygen.

Will water absorb gases, and under what conditions is absorption greatest?

Water will absorb gases, and to the greatest extent when the pressure of the gas upon the water is greatest, and when the temperature is the lowest, for the elastic force of gas is then less.

Of what is air composed, and in what proportions?

Air is composed of about one-fifth oxygen and four-fifths nitrogen, with a small amount of carbonic acid gas.

Describe the principle of circulation.

To illustrate, we will expose a piece of ice to heat. The ice is composed of innumerable small particles, each one in constant motion.

As the ice is heated, these particles begin to expand, and their vibrations increase in rapidity, finally to such an extent that

the particles will no longer hold together, but separate from the solid mass, and become water.

As the heat continues, expansion still continues, each heated particle striving to rise, which of course forces the colder particles to fall and fill the vacant space.

Up to this point the action has been just what takes place in the circulation of hot water.

At last, however, the water becomes so heated that expansion becomes stronger than atmospheric pressure, the particles escape from the mass of water, and being lighter now than the air itself, pass off in the form of steam. Being lighter than the air they of course rise, and here again we have circulation, that is, the circulation of steam. These principles underly all circulation work, both hot water, steam and hot air.

What is the elastic force of steam?

The elastic force of steam is equal to the pressure under which it is generated. If generated under a pressure of 15 pounds, its elastic force when free will be 15 pounds.

Explain the action of the syphon.

The syphon consists primarily of a bent tube, one arm being longer than the other. The syphon transfers liquids from a higher to a lower level. In order to start the syphon the air in the long arm must first be exhausted. As soon as this vacuum is formed, atmospheric pressure forces the water up the short arm, and into the long arm, through which it passes out.

This action continues, unless broken by other means, until the short arm no longer dips into the water.

How may the action of the syphon be destroyed?

By bringing air into the crown of the syphon.

CHAPTER XXVII

MISCELLANEOUS INFORMATION

At what temperature does water boil?

At the sea level, water boils at 212 degrees.

At what temperature does water boil in vacuum?

At 98 degrees.

What is the weight of a gallon of water?

8 $\frac{1}{3}$ pounds.

What are the cubic contents of a gallon of water?

231 cubic inches.

What is the weight of a cubic foot of water?

62 $\frac{1}{2}$ pounds.

How many gallons does a cubic foot of water contain?

A cubic foot of water contains 1728 cubic inches, or 7 $\frac{1}{2}$ gallons.

What is the expansion of water in freezing?

About one-tenth of its volume.

What is the expansion of water in boiling?

About one-twentieth of its volume.

What is the expansion of water in changing to steam?

In changing to steam water expands 1700 times its volume. Approximately 1 cubic inch of water produces 1 cubic foot of steam.

At what temperature does water occupy the least space?

At 39 degrees.

What is the pressure of a column of water?

A column of water 27.67 inches in height produces 1 pound

pressure, and it is commonly estimated that one foot of water gives a pressure of one-half pound.

What substance absorbs and throws out more heat than any other substance?

Water.

What are the cubic contents of 1 pound of air?

One pound of air contains 13.817 cubic feet.

What is a unit of heat or British Thermal Unit (B. T. U.)?

The unit of heat, or the British Thermal Unit now used as the standard measure of heat, is the amount of heat required to raise 1 pound of water or 1 cubic foot of air, 1 degree in temperature.

How many heat units are required to raise 1 cubic foot of air from zero to 70 degrees?

About 1.5 heat units.

How many heat units are required to evaporate one pound of water to steam?

At atmospheric pressure, 966.1 heat units are required to do this work.

How many heat units are contained in a pound of anthracite coal?

About 14,500 heat units.

What is one horsepower equivalent to in heat units?

One horsepower is equivalent to 42.75 heat units per minute.

What is one horsepower equivalent to in mechanical work?

It is the amount of work required to raise 33000 pounds 1 foot high in one minute.

What work is one horsepower equivalent to in low pressure heating?

One horsepower represents the amount of condensation from 100 square feet of direct low-pressure radiation.

To produce one horsepower what amount of evaporation is necessary?

The evaporation of 2.655 pounds of water is required to produce one horsepower,

What are the cubic contents of a ton of anthracite coal?

A ton of anthracite coal contains about 40 cubic feet.

What are the cubic contents of a ton of bituminous coal?

A ton of bituminous coal contains about 49 cubic feet.

What is the weight of a bushel of anthracite coal?

About 86 pounds.

What is the weight of a bushel of bituminous coal?

About 76 pounds.

What is the weight of cast iron?

1 cubic inch of cast iron weighs .26 pound.

What is the weight of wrought iron?

1 cubic inch of wrought iron weighs .28 pound.

VELOCITY OF FLOW OF WATER IN FEET PER MINUTE,
FOR VARYING QUALITY OF FLOW, THROUGH PIPES
OF VARIOUS SIZES

Gals. per Minute	$\frac{3}{4}$ inch	1 inch	$1\frac{1}{4}$ inch	$1\frac{1}{2}$ inch	2 inch	$2\frac{1}{2}$ inch	3 inch	4 inch
5	218	122½	78½	54½	30½	19½	13½	7¾
10	436	245	157	109	61	38	27	15½
15	653	367½	235½	163½	91½	58½	40½	23
20	872	490	314	218	122	78	54	30¾
25	1090	612½	392½	272½	152½	97½	67½	38½
30		735	451	327	183	117	81	46
35		857½	549½	381½	213½	136½	94½	53¾
40		980	628	436	244	156	108	61½
45		1102½	706½	490½	274½	175½	121½	69
50			785	545	305	195	135	76¾
75			1177½	817½	457½	292½	202½	115
100				1090	610	380	270	153½
125					762½	487½	337½	191¾
150					915	585	405	230
175					1067½	682½	472½	268½
200					1220	780	540	306¾

APPROXIMATE MELTING POINTS OF METALS

Mercury	-39 deg. Fahr.	Silver	1850 deg. Fahr.
Tin	442 "	Brass	1900 "
Bismuth	510 "	Gold	2100 "
Lead	618 "	Copper	1975 "
Zinc	750 "	Cast Iron	2100 "
Aluminum	1150 "	Steel	2532 "
Bronze	1692 "	Wrought Iron...	2850 "
Alloy, 3 Lead, 2 Tin, 1 Bismuth.....	199		"
Alloy, 1½ Tin, 1 Lead.....	334		"
Alloy, 1 Tin, 1 Lead.....	466		"

CHAPTER XXVIII

RECIPES, PRACTICAL SUGGESTIONS, ETC.

To Cut a Crooked Thread:

Use a loose bushing.

To Cut a Thread a Little Smaller than Standard:

Insert a narrow strip of tin between the die and pipe on one side. This will force the opposite side of the die to cut a little deeper.

To Start a Hard Thread:

Heat the fitting, and run a little beeswax into the thread. The beeswax will penetrate into the thread, and usually enables the joint to be unscrewed.

To make Coil with Lock-Nuts, when Tees or Manifolds are used:

Cut threads about twice the ordinary length, screw the lock-nut on as far as possible, then screw the long-threaded end of the pipe into the tee until it strikes the shoulder. Then turn back, screwing the other end of the pipe into the fitting until it makes a tight joint. Around the lock-nut end, wind a little asbestos packing about the thread, when it is screwed up, making a tight joint.

To get a 45 degree Measurement between Two Parallel Lines of Pipe:

Add to the distance between the centers of the two parallel lines of pipe, 5 inches for each foot of such distance, and at the same rate for fractional parts of a foot. This will give a close approximation to the true measurement.

To be more exact, add 13-32-inch to every inch of distance between the two lines.

To make a Strong Cement:

Melt over a slow fire, equal parts of rubber and pitch. When wishing to apply the cement, melt and spread it on a strip of strong cotton cloth.

To Cement Iron and Stone:

Mix 10 parts of fine iron filings, 30 parts of plaster of Paris, and $\frac{1}{2}$ part of sal ammoniac, with weak vinegar. Work this mixture into a paste and apply quickly.

To make a Cement for Steam Boilers:

Four parts of red or white lead mixed in oil, and 3 parts of iron borings, make a good soft cement for this purpose.

To make a Cement for Leaky Boilers:

Mix 1 part of powdered litharge, 1 part of fine sand, and $\frac{1}{2}$ part of slacked lime with linseed oil, and apply quickly as possible.

To make Tight Steam Joints:

With white lead ground in oil, mix as much manganese as possible with a small amount of litharge. Dust the board with red lead, and knead this mass by hand into a small roll, which is then laid on the plate, oiled with linseed oil. It can then be screwed into place.

To make a Substitute for Fire Clay:

Mix common earth with weak salt water.

To make a Rust Joint:

Mix 5 pounds of iron filings, 1 ounce of sal ammoniac, and 1 ounce of sulphur, and thin the mixture with water.

To remove Rust from Steel:

Mix $\frac{1}{2}$ ounce of cyanide of potassium, $\frac{1}{2}$ ounce of castile soap, 1 ounce of whiting, adding enough water to form a paste, and apply to the steel. Rinse it off with a solution formed of $\frac{1}{2}$ ounce of cyanide of potassium and 2 ounces of water.

To clean Rusted Iron:

Place the articles to be cleaned, in a saturated solution of chloride of tin and allow them to stand for a half day or more.

When removed, wash the articles in water, then in ammonia. Dry quickly, rubbing them hard.

To remove Boiler Scale:

Kerosene oil will accomplish this purpose, often better than specially prepared compounds.

To clean Brass:

Mix in a stone jar one part of nitric acid, and one-half part

of sulphuric acid. Dip the brasswork into this mixture, wash it off with water, and dry with sawdust. If greasy, dip the work into a strong mixture of potash, soda and water, to remove the grease, and wash it off with water.

To remove Grease Stains from Marble:

Mix $1\frac{1}{2}$ parts of soft soap, 3 parts of Fuller's earth, and $1\frac{1}{2}$ parts of potash, with boiling water. Cover the grease spots with this mixture, and allow it to stand a few hours.

To keep Plaster of Paris from Setting too Quickly:

Sift the plaster into the water, allowing it to soak up the water, without stirring, which would admit air and cause the plaster to set quickly. If desired to keep the plaster soft for a much longer time, add to every quart of water, one-half teaspoonful of common cooking soda. This will gain all the time necessary.

To cut a Gauge Glass Tube:

Wet a three-cornered file, and with the tube held in the left hand, with thumb and forefinger where the cut is to be made, file quickly and lightly several times, to mark the cut on the tube. With the tube in both hands, and each thumb on opposite sides of the mark, bend the tube, and it will break at the mark.

To find the Diameter of a Pump Cylinder to Move a given Quantity of Water per Minute, 100 feet of Piston being the Standard:

Divide the number of gallons by 4, and take the square root of the result. This will give the required diameter in inches.

To find the Velocity in feet per Minute Necessary to Discharge a given Volume of Water in a given Time:

Multiply the number of cubic feet of water by 144, and divide the result by the area of the pipe in inches.

To find the Horsepower to Raise Water to a given Height:

Multiply the total pounds of water by the height in feet, and divide by 33,000. Add to this result about 25 per cent. for friction, etc.

CHAPTER XXIX

RULES

To find the Area of a Rectangle:

Multiply the length by the breadth.

To find the Area of a Triangle:

Multiply the base by one-half the perpendicular height.

To find the Circumference of a Circle:

Multiply the diameter by 3.1416.

To find the Area of a Circle:

Multiply the diameter by itself, and the result by .7854.

To find the Diameter of a Circle of a given Area:

Divide the area by .7854, and find the square root of the result.

To find the Diameter of a Circle which shall have the same Area as a given Square:

Multiply one side of the square by 1.128.

To find the Number of Gallons in a Cylindrical Tank:

Multiply the diameter in inches by itself, this by the height in inches, and the result by .0034.

To find the Number of Gallons in a Rectangular Tank:

Multiply together the length, breadth and height in feet, and this result by 7.4. If the dimensions are in inches, multiply the product by .004329.

To find the Pressure in Pounds per Square Inch, of a Column of Water:

Multiply the height of the column in feet by .434.

To find the Head in Feet, the Pressure being Known:

Multiply the pressure per square inch by 2.31.

To find the Lateral Pressure of Water upon the Side of a Tank:

Multiply in inches, the area of the submerged side, by the pressure due to one-half the depth.

Example—Suppose a tank to be 12 feet long and 12 feet deep. Find the pressure on the side of the tank.

$144 \times 144 = 20,736$ square inches area of side.

$12 \times .43 = 5.16$, pressure at bottom of tank. Pressure at top of tank is 0. Average pressure will then be 2.6. Therefore $20,736 \times 2.6 = 53,914$ pounds pressure on side of tank.

To find the Number of Gallons in a Foot of Pipe of Any Size:

Multiply the square of diameter of the pipe in inches, by .0408.

To find the Diameter of Pipe to Discharge a given Amount of Water per Minute in Cubic Feet:

Multiply the square of the quantity in cubic feet per minute by 96. This will give the diameter in inches.

To find the Size of Pipe Necessary to Fill a Number of Smaller Pipes:

Suppose it is desired to fill from one pipe, a 2-inch, $2\frac{1}{2}$ -inch and 4-inch pipe. Draw a right angle, one arm of the angle 2 inches in length, the other $2\frac{1}{2}$ inches. Draw a line between the ends of these two arms. The length of this line in inches will give the size of pipe necessary to fill the two smaller sizes, about $3\frac{3}{4}$ inches. From one end of this last line, draw another line at right angles to it, 4 inches long. Now from the other end of the $3\frac{3}{4}$ -inch line draw a line to the end of the line last drawn. Its length in inches will represent the size of the pipe necessary to fill a 2, $2\frac{1}{2}$ and 4-inch pipe. This may be continued with any number of sizes.

To find the Power Necessary to Raise Water to Any given Height:

Multiply the number of cubic feet required per minute by the number of feet through which it is to be raised. Then multiply this result by 6.23, and divide by 33,000, which will give the nominal horsepower required. If the amount of water required per minute is in gallons, the multiplier should be 8.3 instead of 6.23.

To prove a Right Angle:

Measure off six inches on one side and eight inches on the other side of the angle to be tested. If the angle is square, it will measure ten inches across, between the two points. This rule will hold good also in feet.

To reduce Centigrade Temperature to Fahrenheit:

Multiply the Centigrade temperature by 9, divide the result by 5, and add 32.

To reduce Fahrenheit Temperature to Centigrade:

Subtract 32 from the Fahrenheit temperature, multiply by 5, and divide by 9.

To find the Area of a Required Pipe, when the Amount and Velocity of the Water are given:

Multiply the number of cubic feet of water by 144, and divide this amount by the velocity in feet per minute.

CHAPTER XXX

TABLES OF WEIGHTS, MEASURES, ETC.

Linear Measure

12	inches (in.)	=	1 foot	ft.
3	feet	=	1 yard	yd.
5.5	yards	=	1 rod	rd.
40	rods	=	1 furlong	fur.
8	furlongs	=	1 mile	mi.

Square Measure

144	square inches (sq.in.)	=	1 square foot	sq. ft.
9	square feet	=	1 square yard	sq. yd.
30¼	square yards	=	1 square rod	sq. rd.
160	square rods	=	1 acre	A.
640	acres	=	1 square mile	sq. mi.

Cubic Measure

1,728	cubic inches (cu. in.)	=	1 cubic foot	cu. ft.
27	cubic feet	=	1 cubic yard	cu. yd.
128	cubic feet	=	1 cord	cd.
24¾	cubic feet	=	1 perch	P.

Dry Measure

2	pints (pt.)	=	1 quart	qt.
8	quarts	=	1 peck	pk.
4	pecks	=	1 bushel	bu.

Liquid Measure

4	gills (gi.)	=	1 pint	pt.
2	pints	=	1 quart	qt.
4	quarts	=	1 gallon	gal.
31½	gallons	=	1 barrel	bbbl.
2	barrels, or 63 gallons	=	1 hogshead	hhd.

Avoirdupois Weight

437.5	grains (gr.)	=	1 ounce	oz.
16	ounces	=	1 pound	lb.
100	pounds	=	1 hundredweight	cwt.
2	cwt., or 2,000 lbs.	=	1 ton	T.

Long Ton Table

16	ounces.....	= 1 pound.....	lb.
112	pounds.....	= 1 hundredweight.....	cwt.
20	cwt., or 2,240 lbs.....	= 1 ton.....	T.

Troy Weight

24	grains (gr.).....	= 1 pennyweight.....	pwt.
20	pennyweights.....	= 1 ounce.....	oz.
12	ounces.....	= 1 pound.....	lb.

Measure of Angles or Arcs

60	second (").....	= 1 minute.....	'
60	minutes.....	= 1 degree.....	°
90	degrees.....	= 1 rt. angle or quadrant.....	
360	degrees.....	= 1 circle.....	cir.

Miscellaneous Table

12	articles.....	= 1 dozen	20	quires.....	= 1 ream
12	dozen.....	= 1 gross	1	league.....	= 3 miles
12	gross.....	= 1 great gross	1	fathom.....	= 6 feet
2	articles.....	= 1 pair	1	hand.....	= 4 inches
20	articles.....	= 1 score	1	palm.....	= 3 inches
24	sheets.....	= 1 quire	1	span.....	= 9 inches

The Metric System:

A system of measurements much simpler and more scientific than the common system, is that known as the metric system. In this system the unit of length is the metre, which is a trifle longer than a yard. All other units of length are multiples or submultiples of ten of the metre. The metric table is as follows:—

10	millimetres=1 centimetre
10	centimetres=1 decimetre
10	decimetres=1 metre
10	metres=1 dekametre
10	dekametres=1 hectometre
10	hectometres=1 kilometre

How are units of area and of volume obtained in the metric system?

Units of area are found by squaring the units of length.
Units of volume are found by cubing the units of length.

What is the unit of weight in the metric system?

The unit of weight in the metric system is the gram, and it is such an amount of pure water at 4 degrees Centigrade as will

fill a cubic centimetre. All other units are multiples or sub-multiples of ten of the gram.

What are the equivalents between the British and metric units?

These equivalents are in part as follows:—

Length:

- 1 metre=39.37 inches
- 1 metre=1.094 yards
- 1 inch=2.54 centimetres
- 1 centimetre=.394 inches
- 1 kilometre=.621 mile

Volume:

- 1 cubic centimetre=.061 cubic inches
- 1 cubic inch=16.386 cubic centimetres
- 1 cubic foot=.028 cubic metres

Mass:

- 1 grain=15.4323 grains
- 1 kilogram=2.2046 pounds
- 1 pound=456.3 grams

CHAPTER XXXI

MISCELLANEOUS TABLES

Pressure of Water at Different Elevations

Head in ft.	Pressure in lb. per sq. in. at base	Head in ft.	Pressure in lb. per sq. in. at base
1	.43	185	80.14
2	.86	190	82.30
3	1.30	195	84.47
4	1.73	200	86.63
5	2.16	205	88.80
10	4.33	210	90.96
15	6.49	215	93.14
20	8.66	220	95.30
25	10.82	225	97.49
30	12.99	230	99.63
35	15.16	235	101.79
40	17.32	240	103.96
45	19.49	245	106.13
50	21.65	250	108.29
55	23.82	255	110.46
60	25.99	260	112.62
65	28.15	265	114.79
70	30.32	270	116.96
75	32.48	275	119.12
80	34.65	280	121.29
85	36.82	285	123.45
90	38.98	290	125.62
95	41.15	295	127.78
100	43.31	300	129.95
105	45.48	310	134.28
110	47.64	320	138.62
115	49.81	330	142.95
120	51.98	340	147.28
125	54.15	350	151.61
130	56.31	360	155.94
135	58.48	370	160.27
140	60.64	380	164.61
145	62.81	390	168.94
150	64.97	400	173.27

155	67.14	500	216.58
160	69.31	600	259.90
165	71.47	700	303.22
170	73.64	800	346.54
175	75.80	900	389.86
180	77.97	1000	433.18

Note: For pressure not given in this table multiply head in ft. by 0.434; the product will be the pressure per square inch at base.

Pressure and Equivalent Feet Head of Water

Pounds per Square Inch	Feet Head	Pounds per Square Inch	Feet Head	Pounds per Square Inch	Feet Head
1	2.31	40	92.36	170	392.52
2	4.62	50	115.45	180	415.61
3	6.93	60	138.54	190	438.90
4	9.24	70	161.63	200	461.78
5	11.54	80	184.72	225	519.51
6	13.85	90	207.81	250	577.24
7	16.16	100	230.90	275	643.03
8	18.47	110	253.98	300	692.69
9	20.78	120	277.07	325	750.41
10	23.09	125	288.62	350	808.13
15	34.63	130	300.16	375	865.89
20	46.18	140	323.25	400	922.58
25	57.72	150	346.34	500	1154.48
30	69.27	160	369.43	1000	2308.00

Number of Gallons Contained in Given Number of Cubic Feet

Cubic Ft.	Gallons	Cubic Ft.	Gallons	Cubic Ft.	Gallons
0.1	0.75	50	374.0	9,000	67,324.6
0.2	1.50	60	448.8	10,000	74,805.2
0.3	2.24	70	523.6	20,000	149,610.4
0.4	2.99	80	598.4	30,000	224,415.6
0.5	3.74	90	673.2	40,000	299,220.7
0.6	4.49	100	748.0	50,000	374,025.9
0.7	5.24	200	1,496.1	60,000	448,831.1
0.8	5.98	300	2,244.1	70,000	523,636.3
0.9	6.73	400	2,992.2	80,000	598,441.0
1	7.48	500	3,740.2	90,000	673,246.7
2	14.9	600	4,488.3	100,000	748,051.9
3	22.4	700	5,236.3	200,000	1,496,103.8
4	29.9	800	5,984.4	300,000	2,244,155.7
5	37.4	900	6,732.4	400,000	2,992,207.6
6	44.9	1000	7,480.0	500,000	3,740,259.5
7	52.4	2000	14,961.0	600,000	4,488,311.4
8	59.8	3000	22,441.5	700,000	5,236,363.3

9	67.3	4000	29,922.0	800,000	5,984,415.2
10	74.8	5000	37,402.6	900,000	6,732,467.1
20	149.6	6000	44,883.1	1,000,000	7,480,519.0
30	224.4	7000	52,363.6		
40	299.2	8000	59,844.1		

Gallons of Water in Various Sizes of Pipes or Tanks One Foot in Height

$\frac{3}{8}$ inch to 180 inch

Diameter of pipe in inches	Volume in gallons per foot	Diameter of pipe in inches	Volume in gallons per foot
$\frac{3}{8}$	0.005	27	29.7
$\frac{1}{2}$	0.010	28	32.
$\frac{3}{4}$	0.023	29	34.3
1	0.047	30	36.8
$1\frac{1}{4}$	0.064	31	39.2
$1\frac{1}{2}$	0.092	32	41.8
2	0.163	33	44.5
$2\frac{1}{2}$	0.255	34	47.2
3	0.367	35	50.
$3\frac{1}{2}$	0.500	36	52.8
4	0.652	37	55.9
$4\frac{1}{2}$	0.826	38	59.0
5	1.02	39	62.1
$5\frac{1}{2}$	1.23	40	65.3
6	1.47	41	68.6
7	2.00	42	72.1
8	2.61	43	75.5
9	3.30	44	79.1
10	4.08	45	82.7
11	4.93	46	86.5
12	5.87	47	90.2
13	6.89	48	94.0
14	8.00	54	119.
15	9.17	60	147.
16	10.44	66	178.
17	11.80	72	211.5
18	13.20	78	284.4
19	14.70	84	288.1
20	16.34	90	330.8
21	18.00	96	376.3
22	19.75	108	477.3
23	21.57	120	589.0
24	23.50	132	712.7
25	25.50	144	848.2
26	27.60	180	1325.3

**Weight of 1 Cubic Foot of Water at the Various Temperatures
Usually Found Within the Range of House Heating by
Hot Water**

Temperature of Water, Deg. Fahr.	Wt. in Lbs. of 1 Cu. Ft. Water at This Temperature	Relative Volume
40	62.42	1.00001
50	62.41	1.00025
60	62.37	1.00083
70	62.31	1.00196
80	62.23	1.00334
90	62.13	1.00497
100	62.02	1.01491
110	61.89	1.00901
120	61.74	1.00748
130	61.56	1.01409
140	61.37	1.01678
145	61.28	1.01828
150	61.18	1.01983
155	61.08	1.02145
160	60.98	1.02309
165	60.87	1.02480
170	60.77	1.02656
175	60.66	1.02836
180	60.55	1.03024
185	60.44	1.03213
190	60.32	1.03414
200	60.07	1.03820
212	59.76	1.04332
220	59.64	
230	59.38	
250	58.81	
270	58.21	
300	57.25	

This table has been prepared by taking items from a number of different authorities who gave the formula used in preparing their tables, and is believed to be sufficiently accurate for the work to which it should be applied. No one should attempt to seal a job to a pressure of 65 pound actual or 50 pound gauge pressure which is about what 300 degrees temperature would mean.

Discharge of Water in Cubic Feet per Minute for a Stream
Having an Area of 1 Square Inch From 1-Foot Head to
120-Foot Head

Head	Discharge	Head	Discharge	Head	Discharge
1	3.34	51	23.85	101	33.57
2	4.73	52	24.08	102	33.73
3	5.79	53	24.31	103	33.90
4	6.68	54	24.54	104	34.06
5	7.47	55	24.76	105	34.22
6	8.18	56	24.94	106	34.39
7	8.84	57	25.21	107	34.59
8	9.45	58	25.43	108	34.71
9	10.02	59	25.65	109	34.87
10	10.51	60	25.87	110	35.03
11	11.08	61	26.08	111	35.19
12	11.57	62	26.29	112	35.35
13	12.50	63	26.49	113	35.50
14	12.94	64	26.72	114	35.66
15	13.38	65	26.92	115	35.82
16	13.78	66	27.13	116	35.97
17	14.18	67	27.33	117	36.12
18	14.57	68	27.54	118	36.28
19	14.95	69	27.74	119	36.43
20	15.31	70	27.94	120	36.58
21	15.67	71	28.14	121	36.73
22	16.02	72	28.34	122	36.88
23	16.37	73	28.53	123	37.03
24	16.71	74	28.73	124	37.18
25	17.04	75	28.93	125	37.33
26	17.36	76	29.11	126	37.48
27	17.55	77	29.30	127	37.63
28	17.68	78	29.49	128	37.78
29	17.99	79	29.68	129	37.93
30	18.30	80	29.87	130	38.07
31	18.60	81	30.06	131	38.22
32	18.90	82	30.24	132	38.37
33	19.20	83	30.42	133	38.51
34	19.47	84	30.61	134	38.66
35	19.77	85	30.79	135	38.80
36	20.05	86	30.97	136	38.95
37	20.33	87	31.15	137	39.09
38	20.60	88	31.33	138	39.23
39	20.87	89	31.50	139	39.37
40	21.13	90	31.68	140	39.51
41	21.38	91	31.86	141	39.65
42	21.64	92	32.04	142	39.79

43	21.90	93	32.20	143	39.93
44	22.15	94	32.38	144	40.07
45	22.40	95	32.55	145	40.21
46	22.65	96	32.72	146	40.35
47	22.89	97	32.89	147	40.49
48	23.14	98	33.06	148	40.63
49	23.38	99	33.23	149	40.77
50	23.61	100	33.40	150	40.90

CHAPTER XXXII

FORCED CIRCULATION HOT WATER HEATING SYSTEMS

What is meant by forced hot water heating?

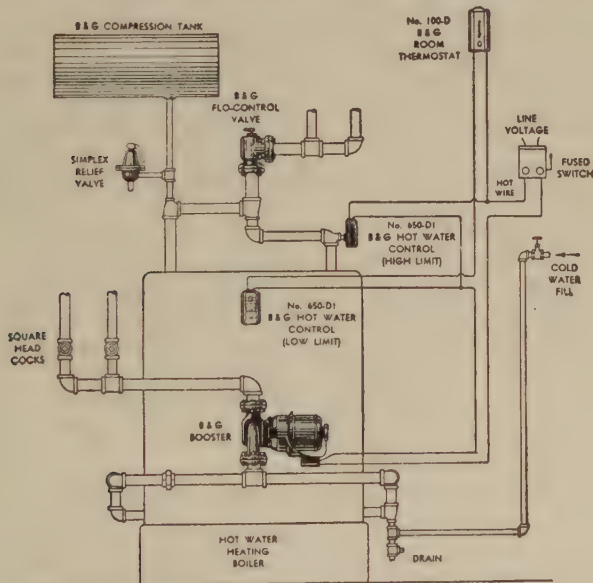
A forced hot water heating system is one in which the hot water is made to circulate by mechanical means.

Into what two principal classes may hot water heating systems now be divided?

Into gravity systems and forced circulation systems.

Is forced hot water heating a recently devised heating system?

Forced hot water heating has come into extensive use only



Reproduced by permission from the B & G Handbook

Fig. 1—Connections for Forced Circulation for coal-fired boiler, without provision for domestic hot water

within a comparatively few years. It is not too much to say, that this method has revolutionized heating.

Explain the difference between the old style hot water heating methods and forced hot water heating.

The forced hot water heating system differs from the common gravity systems in the manner in which circulation is created. In a gravity system circulation is created by the difference in weight between the column of hot water in the supply lines and the cool water in the returns. In a forced hot water system, circulation is created mechanically instead of by gravity; —it is created by a pump installed for the purpose, generally known as a circulator.

How does the forced circulation system of hot water heating operate?

Hot water from the boiler is carried to the radiators by forced circulation which is produced by a circulating pump commonly known as a circulator. The circulator continues to operate until the temperature has been raised to a certain definite point, when a thermostat operates, the circulator stops, and a flow control valve automatically closes communication between boiler and radiators, thereby preventing gravity circulation of the hot water in the heating system. This flow control valve is kept open by the pressure produced in the piping by the circulator, and closes only when the circulator stops operating. It should be observed that the thermostat controls nothing but the circulator.

Under what two types of heating systems is forced circulation applicable?

It may be applied to two different types of heating. In one of these, the water is directly heated in the hot water boiler itself. In the second type, an indirect method of heating is employed, the steam generated in a steam boiler being carried into a coil heater which heats the water passing through it. Indirect heaters of this type are known as hot water converters. The direct heating system has a lower first cost than the indirect method, but the indirect method may under some conditions overcome its higher first cost.

What advantages does forced circulation have?

In forced circulation the hot water travels at greater velocity, and this makes it possible to use considerably smaller sizes of pipe than in gravity systems. This naturally effects a considerable saving in cost of installation.

In this system of heating, temperatures of water in the radiators are practically as high as the temperature in steam ra-

diators; this results in greatly lowering the amount of heating surface required in the forced circulation system.

In forced circulation uniform grading of pipes is not a real necessity. It is possible indeed, in this system, to run pipes almost anywhere and in any manner, and to heat radiation located either above or below the heating main with equal effectiveness. These facts however, should not be made an excuse for installing piping in any but a correct, workmanlike manner.

Radiators may be located wherever desired; boilers likewise may be located wherever most convenient; mains, risers, connections to radiators may be run under practically any system or layout of piping.

The boiler works with greater efficiency, due to a more rapid passage of water through the boiler, and over the heating surfaces. There is a saving in fuel, owing to the fact that complete circulation can be produced throughout the heating system, without the necessity of heating all the water in the system, which is necessary under gravity circulation. This means that satisfactory circulation can be kept up in mild weather, under circumstances where this is impossible with the gravity system.

What advantages come from the increased velocity in forced circulation systems?

Smaller sizes of pipe may be used than in the gravity system, and radiators warm up more quickly.

What types of piping are used most advantageously in forced circulation heating systems?

This system is generally installed with a one-pipe or a two-pipe system.

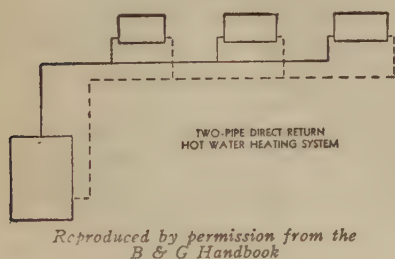
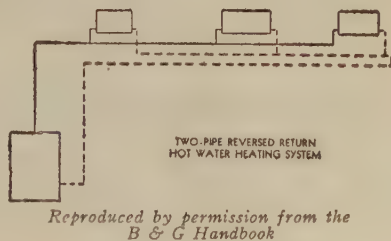


Fig. 3.—

Two-Pipe Reversed Return
Hot Water Heating System

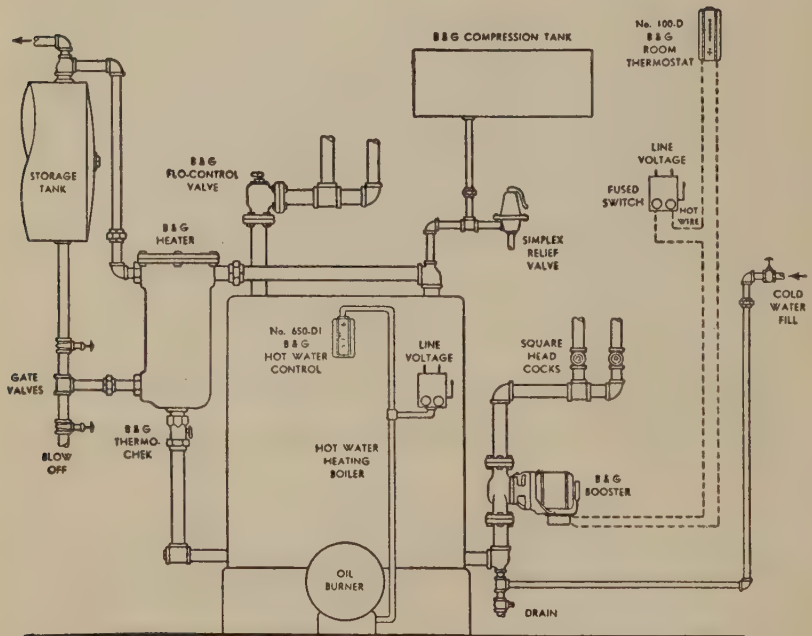
Fig 2—

Two-Pipe Direct Return Hot
Water Heating System



Why is a reverse return system of piping preferable to a simple direct return system in forced circulation?

The simple direct return system, as shown in Fig. 2, is subject to serious effects from errors in design, whereas there is no such danger in the use of the reversed return system as shown in Fig. 3. If there should be a mistake in sizing a radiator pipe in the reversed return system, the radiator would still receive a supply of hot water, owing to the fact that the length of all circuits in this system are about the same, and resistance to flow therefore nearly equal. Cost of installing the two systems is about the same.



Reproduced by permission from the B & G Handbook

Fig. 4—Forced Circulation Hot Water Heating System with Indirect Water Heater

Is the use of forced circulation confined to small systems of heating?

By no means. On the contrary, forced circulation can be used on much larger heating systems than is possible to use the gravity heating system.

Describe the general construction and operation of the circulating device used in forced circulation.

There are several of these devices on the market, variously known as hot water circulators, boosters, circulating pumps, etc. In general these devices are of the centrifugal pump type, and in the form of a propellor rotating in the return line, whose purpose is to set the water in motion through the piping of the heating system. The propellor is generally directly connected to the shaft of a small motor. Some of these circulators operate vertically, and others horizontally.

How do circulators range in size?

While there is considerable difference in the several makes of circulators, the following data concerning one of the important makes, will serve to show something of this range.

Pipe Size Diameter	Amount Radiation
1-inch	Up to 500 sq. ft.
1¼-inch	Up to 800 sq. ft.
1½-inch	Up to 1500 sq. ft.
2-inch	Up to 2500 sq. ft.
3-inch	Up to 5000 sq. ft.

Where should the circulator be installed?

In the return main, as close to the boiler as possible, as shown in Figs. 1 and 5.

Do circulating pumps operate continuously?

These pumps are operated continuously or intermittently, according to the type of temperature used.

What precaution should be taken against sudden failure of the circulator?

A by-pass should be used, so that circulation may continue to some extent in the event of failure of the circulator to operate. The by-pass should be valved. The by-pass will provide enough circulation to keep the building partially warmed. In large heating systems it is a good plan to have two pumps, so that the failure of one may not entirely deprive the building of heat.

What is the purpose of the flow control valve?

This valve controls the flow of water from the boiler through the main flow line. It remains closed when the circulator is not running. As soon as the circulator starts, however, the force of the water opens the flow control valve. Closing of this valve prevents gravity circulation to the radiators, thus preventing over-heating.

Do all flow control valves remain closed when the circulator is not working?

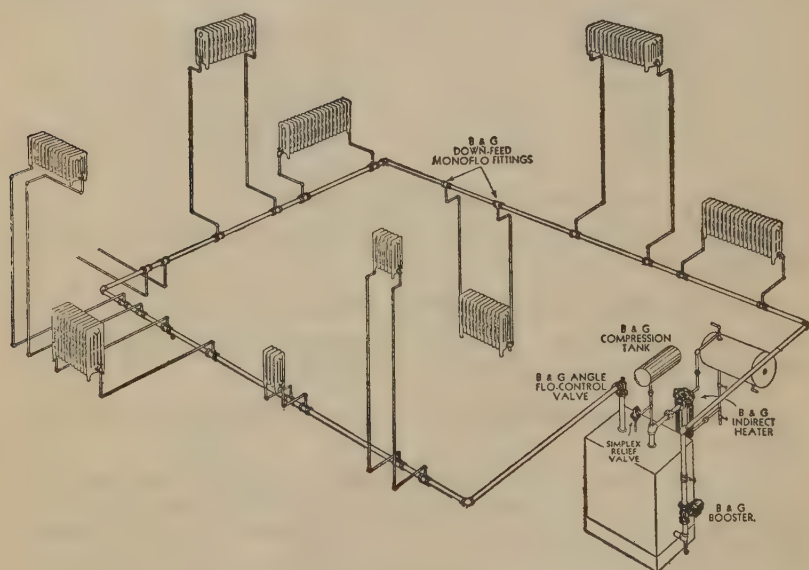
Some of the flow control valves have a hand control device which allows the valve to be opened by hand in the event that anything happens to the circulator.

Where should the flow control valve be placed?

It should be placed in the main flow line, near the boiler, as shown in Figs. 1 and 5.

Is an expansion or compression tank used in forced circulation heating systems?

It is preferable to run such a system closed, with a compression tank connected to the high point of the main flow line, as it leaves the top of the boiler.



Reproduced by permission from the B & G Handbook

Fig. 5—A Typical Single Circuit Forced Circulation Hot Water Heating System

What is the purpose of the compression tank in forced circulation?

Such a tank takes care of the hot water, providing a cushion of compressed air against sudden pressure and shocks from water hammer, which might do harm to the boiler.

Why is it absolutely necessary to use a compression tank on high temperature systems?

It is necessary in order to allow sufficient pressure to be produced to prevent boiling of the water in the heating system.

Where may compression tanks be placed on a forced circulation system?

They may be installed either in the basement or at any other convenient point.

What size of compression tank should be used on a forced circulation system?

The following sizes of compression tanks will be found acceptable:—

Tank Capacity	Square Feet Radiation
18 gals.	Up to 500
24 gals.	Up to 1000
30 gals.	Up to 2000
35 gals.	Up to 2500
40 gals.	Up to 3000
60 gals.	Up to 4000
80 gals.	Up to 4500

The above are commercial sizes. Often however, it will be found advisable to use tanks of somewhat larger capacity.

In forced circulation how is the main flow line generally run?

In either the one-pipe or two-pipe systems, the main flow or distributing line may be carried in the cellar, with branches rising to the various radiators, or the main flow line may be run in the attic, with the main return in the cellar.

In forced circulation systems where can radiators be placed?

Radiators may be located far below the boiler, on the same level with it, or above it. If the piping is correctly designed, there need be no difference in efficiency of operation.

In forced circulation how may basement radiators be connected which set on the floor?

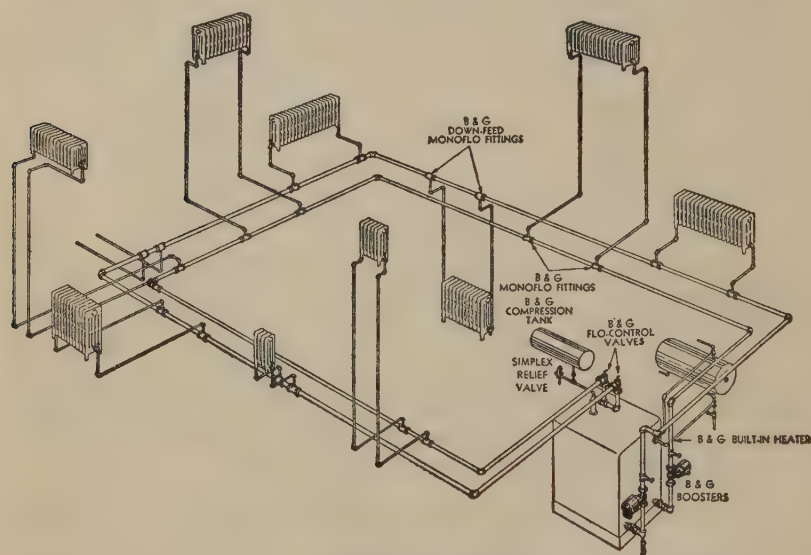
Such radiators may be piped from mains carried on the basement ceiling. This shows one of the chief advantages of the forced circulation system,—that it is not necessary in this system, to run returns below radiators, as in the case of steam heating.

Can the indirect domestic hot water heater be used in forced circulation?

Use of the indirect heater in connection with a forced hot water heating system is one of its most important applications. See Fig. 4 for connections. Also refer to Chapter XXIV.

Where should the boiler be located on a forced circulation heating system?

Generally speaking, the boiler may be located wherever most convenient. However, it is best to locate it where a minimum of pipe will be called for in the mains. Also, it is best to locate the boiler as close as practicable to the chimney.



Reproduced by permission from the B & G Handbook

Fig. 6—A Typical Installation for a Two-Zone Forced Circulation Hot Water Heating System

How may heating mains be run in this system?

When necessary it is entirely proper to run one part of a circuit at a higher level than the rest of it, or to run one circuit at a different level than another circuit, or to run one main to circuits on a different level than circuits served by another main.

What may be said about the relative size of piping in gravity and forced circulation systems?

Much smaller sizes of pipe may be used in forced circulation.

Why can smaller pipe be used in forced circulation?

The velocity of flow of water is much higher in forced circulation systems of heating than in gravity systems. These greater velocities make it possible to use much smaller sizes of pipe in forced circulation.

Upon what does the proper flow of hot water depend in a forced circulation heating system?

The friction head must be equalled by the pressure head, pressure head in this system being the head created by the circulator. Because of the pressure head, there must be an equal amount of friction head in the heating system to offset it, and this friction is created by decreasing the size of the piping.

What is the most vital feature of a forced circulation system?

The most vital point is that the piping shall be properly sized. Regardless of the method used, pipe sizing is based on the fundamental requirement that the frictional resistance to the flow of water must be the same in all circuits, to produce correct distribution of hot water, and to avoid short circuits.

In general, what are the principal points to be taken into consideration in the estimating of pipe sizes for forced H. W. heating systems?

The starting point in the estimating of pipe sizes for a heating system, is to know the amount of radiation required.

Another point is to decide on the temperature drop, that is, the difference in temperature of water entering and leaving the boiler. This varies between 20 and 30F. However, for most economical operation of ordinary heating systems, a 20F drop is generally found to be satisfactory.

A third point is to decide upon the amount of head the heating system is to work against. This head runs between 2 and 5 ft. in common heating systems, and might be as great as 100 ft. in the case of large buildings.

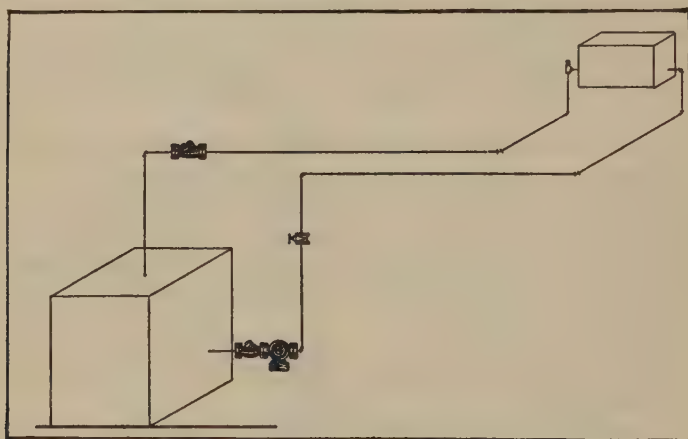
An important matter is the estimating of friction or resistance to flow of water in the piping.

A final point,—In pipe-sizing a forced circulation system, it is necessary to have a plan or sketch of the entire installation, drawn to scale, and showing the various fittings, valves, radiators, etc.

Describe the method used in estimating the friction of the piping in a forced circulation system.

Friction or resistance of the piping to the flow of water, must be estimated, in order to find correct sizes. Each foot of pipe presents a certain amount of friction, and likewise, each fitting, radiator, etc., causes a certain amount of friction to the flow of water. It is possible to find the total amount of friction in the piping, including fittings, valves, etc.

Friction of fittings, valves, etc., may be expressed in terms of one 90-degree elbow. In this estimating, the friction of a 90-degree elbow is given a value of 1. On the basis of the friction of this fitting as a unit, the comparative friction of other fittings commonly used in hot water heating, have been worked out in accordance with the following table:—



Reproduced by permission from the B & G Handbook

Fig. 7

Table of Elbow Equivalents

1 90° Ell	1	1 Stop Cock Open	1
1 45° Ell	0.7	1 Radiator	3
1 90° Long Turn Ell	0.5	1 Boiler	3
1 Open Return Bend	1	1 Tee	
1 Open Gate Valve	0.5	25% water to Branch	16
1 Open Globe Valve	12	33% " " "	9
1 Angle Radiator Valve	2.0	50% " " "	4
1 Flow Control Valve	2.0	100% " " "	1.8

The friction of one elbow of any given size, is estimated as equal to the resistance offered by 25 diameters of pipe of the same size as the elbow. Thus, friction of one $\frac{1}{2}$ -inch elbow will be $25 \times \frac{1}{2}$ -inch, or $12\frac{1}{2}$ inches of $\frac{1}{2}$ -inch pipe. Likewise a $\frac{3}{4}$ -inch elbow would offer resistance equal to $25 \times \frac{3}{4}$ -inch, or $18\frac{3}{4}$ inches of $\frac{3}{4}$ -inch pipe.

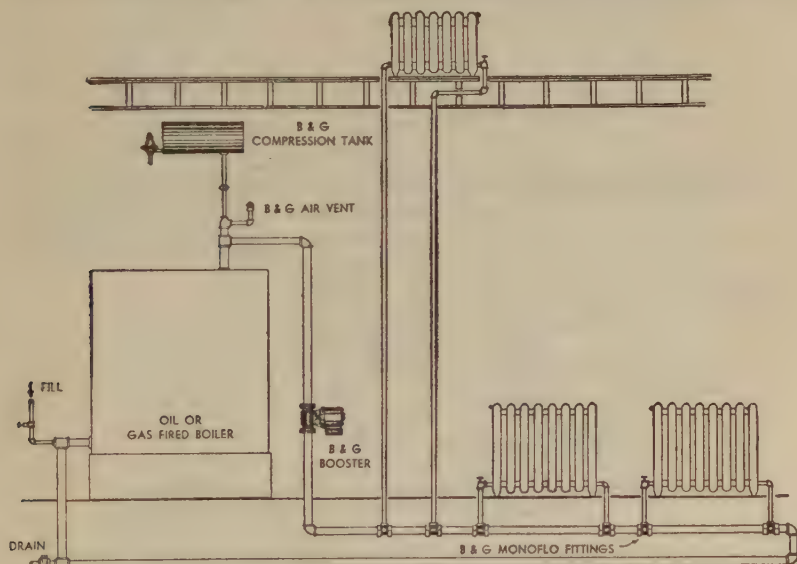
To find the friction of any other fitting, for example a $\frac{3}{4}$ -inch open gate valve, referring to the above table, it is found to be $25 \times \frac{3}{4}$ -inch $\times .5$, or $9\frac{3}{8}$ inches of $\frac{3}{4}$ -inch pipe. Similar use of the table will enable the friction of other fittings and valves to be determined.

Referring to Fig. 7, we will endeavor to find the equivalent total length of piping, supposing the piping to be $\frac{3}{4}$ -inch, and that the total of the straight runs of pipe amount to 96 feet.

Friction is to be taken into account in the following list of fittings, etc., used in Fig. 6, —8 90-degree elbows, 1 stop cock, 1 radiator valve, 2 flow control valves, 1 radiator and 1 boiler. Referring to the Table of Elbow Equivalents, the total friction produced by the above list is as follows:—

	Equivalent
8 90-deg. elbows	8 elbows
1 stop cock	1 elbow
1 radiator valve	2 elbows
2 flow control valves	4 elbows
1 radiator	3 elbows
1 boiler	3 elbows
Total	21 elbows

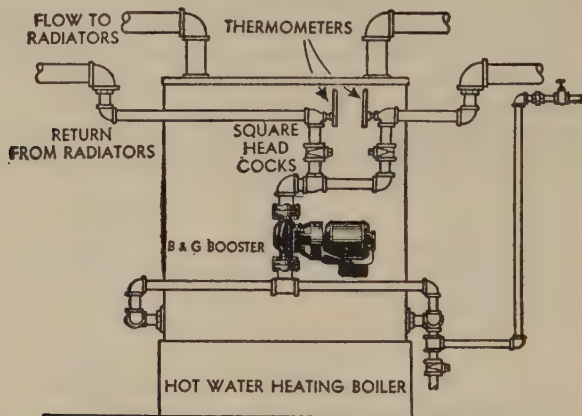
The equivalent length of pipe represented by 21 elbows is as follows:— $21 \times 25 \times \frac{3}{4}$ -inch = 393.75 inches, or approximately 33 feet of $\frac{3}{4}$ -inch pipe. Adding this amount to the straight pipe,



Reproduced by permission from the B & G Handbook

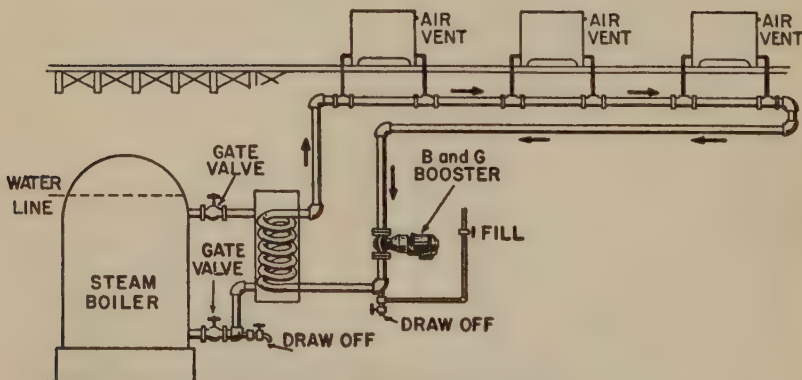
Fig. 8—A Good Method in Forced Circulation Work, When Part of Radiation is on the Level with, or below the Boiler

gives 96 feet + 33 feet = 129 feet of $\frac{3}{4}$ -inch pipe. This means that the heating system shown in Fig. 6, offers an amount of friction or resistance to flow of water through it, equal to the resistance of 129 feet of $\frac{3}{4}$ -inch straight pipe.



Reproduced by permission from the B & G Handbook

Fig. 9—A Hot Water Circulator Used to Improve the Circulation in an Old Gravity Hot Water Heating System



Reproduced by permission from the B & G Handbook

Fig. 10—In Factories, Warehouses and Other Establishments where there is a Steam Boiler, but where Steam Pressure is not Needed Constantly, this Installation is a Good One for Heating the Office with Hot Water

TABLES OF PIPE SIZES, VALVE SIZES, ETC., FOR FORCED HOT WATER HEATING SYSTEMS

The Thrush Company, a leading manufacturer of forced hot water heating devices, recommends the sizing of such heating systems according to the following tables of pipe sizes, etc. A Thrush flow control system of hot water heating is shown in Fig. 6, page 109.

SIZES FOR MAIN SUPPLY PIPES

Steel Pipe

Sq. Ft. of Radiation	Size and Number of Mains
0- 300	one 1"
301- 500	one 1¼" or two 1"
501-1000	one 1½" or two 1¼"
1001-1500	one 2" or two 1½"
1501-2500	one 2½" or two 2"
2501-5000	one 3" or two 2½"

2½" and 3" mains may be reduced to 2" at proper radiation intervals.

SIZES FOR MAIN SUPPLY PIPES

Copper Pipe

Sq. Ft. of Radiation	Size and Number of Mains
0- 300	one ¾", over 50' long, 1"
301- 500	one 1" or two ¾"
501- 800	one 1¼" or two 1"
801-1250	one 1½" or two 1¼"
1251-2000	one 2" or two 1½"
2001-3500	one 2½" or two 2"
3501-7000	one 3" or two 2½"

Mains smaller than 2" should be carried full size to terminating radiator, whether copper or steel.

2", 2½", and 3" mains may be reduced at proper radiation intervals to 1½".

Mains of unusual length or those meeting a special condition should receive special consideration.

VALVE AND RISER SIZES FOR SINGLE RADIATOR ON ANY FLOOR

Steel Pipe

0-100 sq. ft. radiation	½"
over 100 sq. ft. radiation	¾"

Copper Pipe

0- 60 sq. ft. radiation	¾"
60-125 sq. ft. radiation	1½"
over 125 sq. ft. radiation	¾"

Where ¾" lateral branches are over average length, increase to ½" between mains and vertical risers.

Downfeed branches and valves, to radiators on basement floor, to be increased one size.

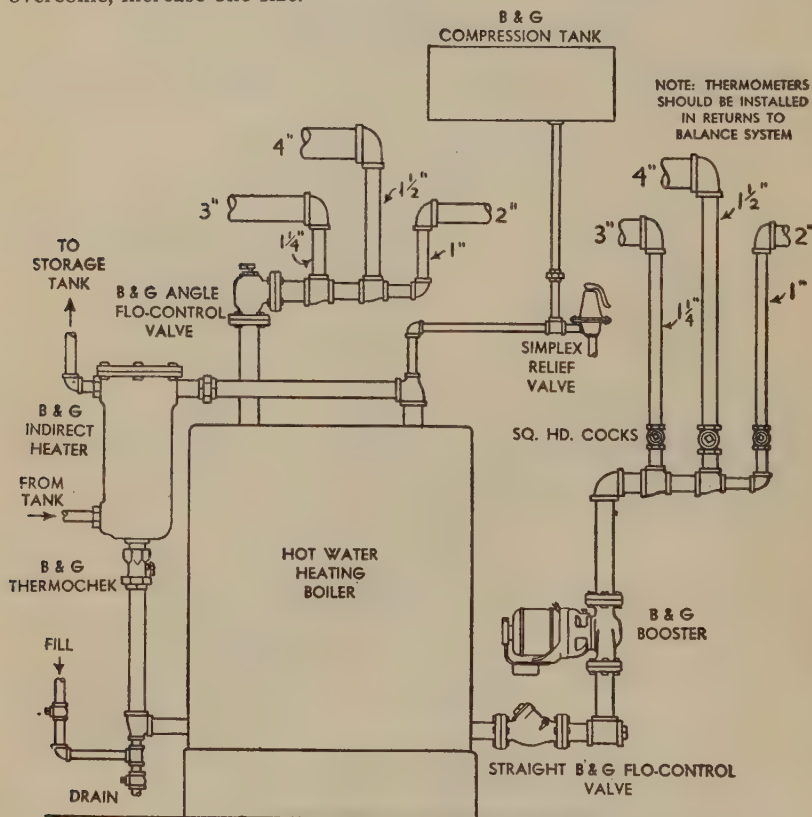
RISERS TO TWO OR MORE RADIATORS ON UPPER FLOORS

	Steel Pipe	Copper Pipe
0—75 sq. ft. total rad.	$\frac{1}{2}$ "	$\frac{1}{2}$ "
75—110 sq. ft. total rad.	$\frac{3}{4}$ "	$\frac{1}{2}$ "
over 110 sq. ft. total rad.	$\frac{3}{4}$ "	$\frac{3}{4}$ "

CIRCULATOR SIZES FOR FLOW CONTROL SYSTEM

1"	Up to 500 sq. ft. radiation
$1\frac{1}{4}$ "	Up to 800 sq. ft. radiation
$1\frac{1}{2}$ "	Up to 1,500 sq. ft. radiation
2"	Up to 2,500 sq. ft. radiation
3"	Up to 5,000 sq. ft. radiation

Capacities apply to average installations. Whenever the mains are unusually long for their size or when some other special condition is to be overcome, increase one size.



Reproduced by permission from the B & G Handbook

Fig. 11—Showing Boiler Connections for Old Gravity Heating System
Converted to a Forced Circulation Heating System

FLOW CONTROL VALVE SIZES

Size	Steel Pipe Sq. Ft. Rad.	Copper Pipe Sq. Ft. Rad.
1"	Up to 300	Up to 500
1¼"	Up to 500	Up to 750
1½"	Up to 1,000	Up to 1,250
2"	Up to 1,500	Up to 2,000
2½"	Up to 2,500	Up to 3,500
3"	Up to 5,000	Up to 7,000

Capacities apply to average installations. Whenever the mains are unusually long for their size or when some other special condition is to be overcome, increase one size.

TANK SIZES FOR FLOW CONTROL SYSTEM

No. 0—12" x 36"	Up to 500 sq. ft. radiation
No. 1—12" x 48"	Up to 1,000 sq. ft. radiation
No. 2—12" x 60"	Up to 2,000 sq. ft. radiation
No. 3—14" x 60"	Up to 3,000 sq. ft. radiation

Above sizes for 1 or 2 story buildings. Use one size larger tank for 3 or 4 story buildings.

FOR THRUSH FLOW CONTROL SYSTEM
CONVERSION JOBS

Use Circulator one size larger than shown in tables and, when boiler is automatically fired, Flow control valve with at least same size connection as Circulator.

Reduce flow and return mains at the boiler to same sizes as shown in tables, using reducing elbows or couplings and connect reduced return mains with Y fittings. Old jobs having ¾", 1", 1¼", 1½" or 2" radiator valves should be reduced to proper sizes with Thrush orifice inserts.

Mains should terminate in first floor radiators where possible. Mains should pitch up from boiler to terminating radiator in the average up-feed installation.

Net boiler sizes should be determined from the total B.T.U. requirement divided by 150, which is conventional method of boiler ratings. Boiler should be chosen on this basis of rating for standing radiation equivalent.

Is it possible and practicable to apply forced circulation to an old gravity hot water heating system?

To convert an old gravity system into a forced circulation heating system is both possible and entirely practicable. Figs. 11 and 12 will be found instructive in relation to this subject.

In converting a gravity system into a forced circulation system, is it necessary to change the radiators and piping?

In making this conversion, it is not necessary to change the radiators, and generally it is not necessary to change the piping, except around the boiler. This is shown in Fig. 11. When there are long circuits on large heating systems that are to be con-

verted, it may be wise to run a return connection to the ends of the supply mains, in order to equalize circulation.

What precaution should be taken in selecting the circulator for a converted heating system?

Owing to the uncertainty of proper design in old systems, and because of the large sizes of pipes, it is generally wise to use a circulator one size larger than for the same amount of radiation on a new forced circulation system. In the event that the main circuits are unusually long, in some instances it may be best to use a circulator two sizes large.

CHAPTER XXXIII

HEATING CONTROL SYSTEMS

Very remarkable progress has been made in recent years by a number of progressive, forward-looking manufacturers, in perfecting and establishing the means of providing "an even flow of just the right amount of heat, constant and continuous," for every room in the home under every possible condition and circumstance.

One of the leaders in this work has been the Minneapolis-Honeywell Company. This company sets forth clearly the results they have attained in this direction in an engineering discussion on "Moduflow Control Systems for Postwar Home Heating." It is from this publication that we are privileged to present the information given in the following pages.

Preceding the information itself, there is an introduction which we reproduce in part, in the following lines:

"The heat in the human body results from the combustion of food. Under ordinary conditions, the body maintains its normal level of 98.6 degrees, and since more heat is usually created than is required to maintain this temperature, heat is lost through radiation, convection, evaporation, and respiration. The body radiates heat to surrounding walls, windows, and other objects which are at a lower temperature. The body gives up heat to the surrounding air by convection when the air is cooler than the body surface temperature. Moisture is constantly evaporating from the body surfaces, which provides for cooling, and air taken into the lungs at normal temperatures is exhaled at higher temperatures, thereby removing a certain amount of heat.

"The human body possesses remarkable power of adaptation to a range of atmospheric conditions. However, there is a narrow range in which a sense of comfort results, and any changes in atmospheric conditions which result in a change in the rate of heat loss, or a change in the manner in which the heat is lost, causes a certain amount of discomfort.

"Conditions affecting comfort which may vary within a home are air temperature, air movement, relative humidity, and the temperature of the walls, windows, and other objects. If any of these conditions change, the body must adapt itself

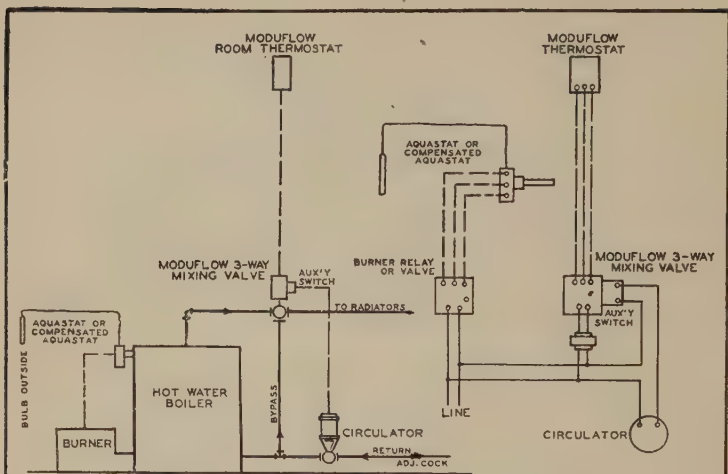


FIG. 1.
SINGLE SECTION MODUFLOW H.W. CONTROL SYSTEM

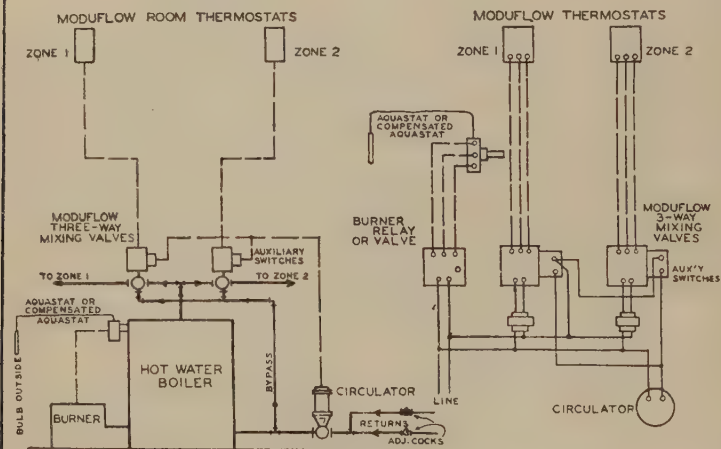


FIG. 2.
MULTIPLE SECTION MODUFLOW H.W. CONTROL SYSTEM

Figs. 1 and 2

to a new condition by a change in the rate of metabolism or a change in the rate or manner of losing heat, thereby establishing a new balance. Therefore, the heating system should maintain a constant condition resulting in a maximum bodily comfort.

"In addition the temperature throughout the room should be maintained as nearly uniform as possible, so that there will be a minimum temperature difference between floor and ceiling. Present day systems maintain this differential at a minimum during firing periods, but during off periods cold air settles to the floor, and an uncomfortable condition prevails even though the thermostat is satisfied. To correct this condition, a constant flow of heat should be maintained which will produce a constant flow of warm air circulation in the room. This will result in minimum temperature differences between floor and ceiling and maintain this narrow range required for maximum human comfort."

"Moduflow" is the trade name given to this control system, the word meaning modulated, measured, or regulated,—that is, modulated heat with continuous flow.

The Moduflow system of control is not a new development, nor an untried experiment. The method has been applied over a period of years in many public and commercial buildings, and has now been adapted to the home.

In the following pages we shall describe three types of heating systems,—hot water, steam and warm air. Each of these may be broken down into a simple single system for the smaller residence, or into a multiple system where two or more sections of the home are controlled independently of each other.

The average home has three natural divisions,—(1) service section, (kitchen, laundry, etc.), (2) living room, dining room section, and (3) sleeping section. The requirements of the three are distinctly different. Each section is controlled to meet the comfort needs of that section. It permits one to be warmer, while the other is cooler, or vice versa. It also makes available, heat normally supplied to an unoccupied section, for other sections in use, which results in fuel savings.

Single Section Hot Water Control System

This method may be applied to forced hot water heating systems using a circulating pump to insure constant circulation. There are various methods of accomplishing this, and one simple application is shown in Fig. 1.

A Moduflow three-way mixing valve is installed in the supply main leaving the boiler, so that one inlet is connected to the hot

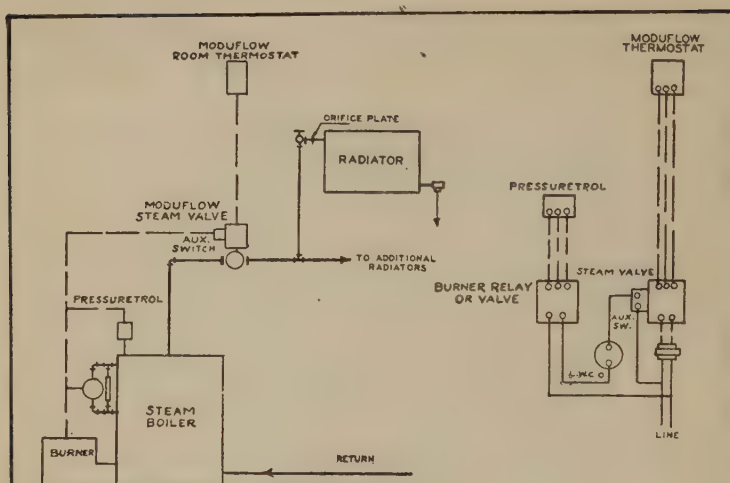


FIG. 3.

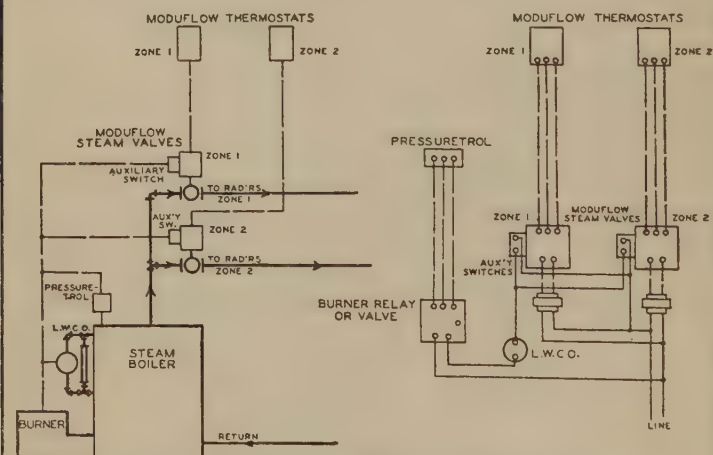
SINGLE SECTION MODUFLOW STEAM CONTROL SYSTEM

FIG. 4.

MULTIPLE SECTION MODUFLOW STEAM CONTROL SYSTEM

Figs. 3 and 4

water supply from the boiler. The other inlet is connected to a by-pass line taken from the return main between the circulator and the boiler. The other is connected to the heating main supplying the radiators throughout the building. Balancing cocks should be installed in the return lines to prevent too rapid circulation of water which may result in overshooting of space temperature under certain conditions, such as during morning pick-up period.

A Moduflow thermostat operates the motorized three-way valve to proportion the quantity of water passing through the boiler with that passing through the by-pass. On a decrease in room temperature below the thermostat setting, the valve is positioned to force more water through the boiler increasing the temperature to the radiators. On a rise in temperature, the amount of water passing through the boiler is decreased, and that through the by-pass increased, to reduce the temperature of the water supplied to the radiators. A constant volume of water is circulated at all times, and the temperature of this water is varied as more or less is allowed to pass through the boiler. The resultant temperature of the water to the radiators is just sufficient to offset the heat loss from the building.

The circulator or pump is run continuously, except when no heating is required, at which time the valve will be completely closed to the boiler and all water is passing through the by-pass. At this time an auxiliary switch on the motor valve stops the circulator, and may shut off the burner if desired.

The temperature of the water in the boiler is maintained with an Immersion Aquastat, and may be of the constant temperature type if an indirect hot water heater is used for domestic hot water. Where the boiler is used for heating only, it is advisable to use a compensated Immersion Aquastat to vary the temperature of the water according to the outside temperature. The Aquastat is equipped with a bulb located outside, and the setting automatically varied between a selected minimum temperature for very mild weather, to the maximum design hot water temperature for extreme weather. The compensated Aquastat decreases the heat loss from the boiler and the boiler casing, and increases the overall efficiency of the heating unit.

Multiple Section Hot Water Control Systems

Fig. 2 shows a two-section hot water control system with Moduflow valves for continuous flow.

Two or more sections may be installed, using the same boiler controls and circulator as previously described. In addition, a Moduflow thermostat and three-way mixing valve are required

for each section. Each valve has one inlet connected into the supply header from the boiler, and the other inlet connected to the by-pass header. The outlet is connected to the main supplying the radiation for the respective section. Care must be taken to lay out and install the piping so that all the radiators heating the space for one section are taken from the main for that section.

Balancing cocks should be installed for each section, to prevent too rapid circulation of the water, which may result in overshooting of space temperatures under certain conditions, such as during the morning pick-up period.

If the system is designed for a small drop in temperature between the supply and return, or if widely different temperatures are required in the various sections, a separate circulator may be required for each section. Otherwise the return water from one section may overheat another section. Balancing cocks may be installed in each section so as to increase the temperature drop between the supply and the return, and thereby in some cases, avoid the necessity of separate circulators for each section. The piping on many of the existing hot water heating systems may be unsatisfactory for the installation of sectional control without changing the basement mains. However, a single section Moduflow heating control system may be installed on existing systems with a minimum of piping changes. The piping layout for new residences may be easily designed for two or more sections as desired. New homes should be carefully checked before construction is started, and the heating designed so that the desired number of sections may be installed.

For either the single section or the multiple section, a clock or Da-Nite thermostat may be used to provide night shutdown. Where sectionalized control is used, each section may be controlled independently. With this type of installation, the auxiliary switches on the valve motors break the circuit to the circulator for the night operation, until the temperature drops below the setting of any thermostat. If this occurs, the circuit is made in the auxiliary switches of the valve motors, starting the circulator as the mixing valves start to open, calling for water through the boiler. The circulator will continue to run so long as any thermostat continues to call for heat during the night period. As soon as the clock thermostats call for day operation, they will control at their daytime temperature setting.

Single Section Steam Control Systems

Fig. 3 shows a typical Moduflow control system, which may be applied only to the two-pipe steam system with a positive

means of returning the condensate to the boiler, such as a boiler return trap or pump.

A Moduflow steam valve is installed in the main of a two-pipe heating system. This valve must be installed in a horizontal line where condensate cannot collect when the valve is in a closed position. The valve is controlled by a Moduflow thermostat located in the space which proportions the amount of steam admitted to the mains according to the heating requirements. Properly sized orifice plates must be installed in each radiator inlet to insure uniform circulation to all radiators. The quantity of steam passing through the valve to the heating system is proportioned according to the demands of the thermostat and is just sufficient to offset the heat loss from the building.

A Pressuretrol on the boiler operates the burner, and maintains a constant pressure at all times except when no heat is required. An auxiliary switch on the control valve may be used to stop the burner when the valve is closed, and return the control to the Pressuretrol whenever the valve is open.

Multiple Section Steam Control Systems

A multiple section Moduflow control system for steam is shown in Fig. 4.

Two or more sections may be installed by adding a Moduflow thermostat and a Moduflow steam valve for each additional section. The burner may be controlled as previously described, and the auxiliary switches on the Moduflow valves are wired in parallel so that pressure is maintained whenever any sectional valve calls for heat. Each radiator must have a correctly sized orifice plate installed at the radiator inlet.

For either the single section or the multiple section, a clock or Da-Nite thermostat may be used to provide night shutdown. Where sectionalized control is used, each section may be controlled independently during both day and night operation. With this type of installation, the burner is shut off during the night period, unless the temperature in the home drops below the setting of any thermostat. If this occurs, the circuit is made in the auxiliary switches of the valve motors, starting the burner as the valves start to open, calling for steam. Steam will then be available so long as any thermostat continues to call for heat during the night period. As soon as the clock thermostats call for day operation, they will control at their daytime temperature setting.

Moduflow is applicable to many existing two-pipe steam systems with minor piping changes at the boiler and the addition of correctly sized orifice plates at each radiator inlet. New sys-

tems should be designed so that piping layout will permit dividing the home into sections according to the respective requirements.

Single Section Warm Air Control Systems

While this book is devoted to the subject of steam and hot water heating, we think it wise to add the following instructions concerning the Moduflow method of controlling warm air systems:—

Moduflow for warm air heating systems means a continuous flow of air with varying temperatures. The temperature of the air leaving the air outlet must be varied from the minimum allowable (and still prevent drafts), up to the maximum required for extreme weather conditions. This may be done in several different ways. Fig. 5 shows one possible method of securing operation of a warm air heating system. Where a modulating burner is available, a Moduflow room thermostat may be used to modulate the burner. In this way the bonnet air temperature and the air outlet temperature vary throughout the complete range of temperatures desired, and the fan runs constantly when heat is required to provide continuous heat flow to the space. An auxiliary switch on the Modulating Control stops the fan motor when no heat is required.

Care must be taken to guard against throttling the burner below practical minimum and likewise, guard against excessive condensation. Another form of Moduflow control system for warm air may be applied where a suitable type of furnace is used. By this we mean furnaces that will stand reduced air volume without overheating a section and causing damage. This system, using a by-pass, is shown in Fig. 6, and requires a furnace that will operate with reduced air flow through the furnace. This is a very satisfactory system and lends itself readily to sectionalized control as discussed later.

The furnace is equipped with a by-pass and mixing damper which is adjusted to vary the quantity of air passing through or around the furnace. The room thermostat controls the Moduflow motor to position the mixing damper, so that the air passing through the furnace is mixed with that which is passed through the by-pass to supply air at the proper temperature to offset the heat loss of the space. On a decrease in room temperature below the thermostat setting, the damper is positioned to allow more air to pass through the furnace. As the room temperature rises, the damper moves to allow less air to pass through the furnace. A constant volume of air is supplied to the heated space at all times, because the quantity passing through the furnace de-

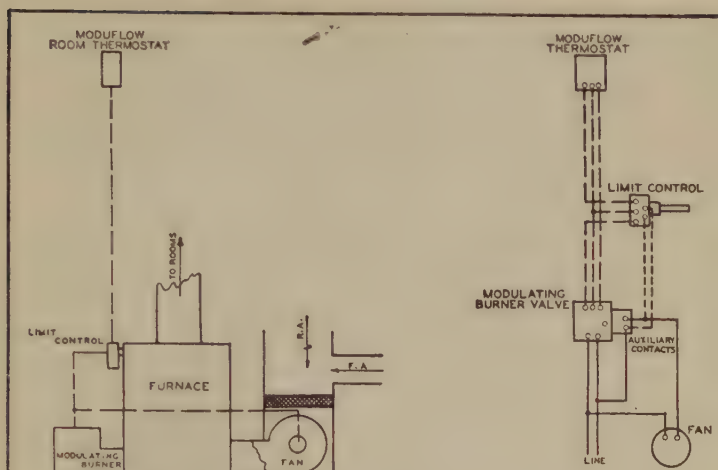


FIG. 5.
SINGLE SECTION MODUFLOW WARM AIR CONTROL SYSTEM

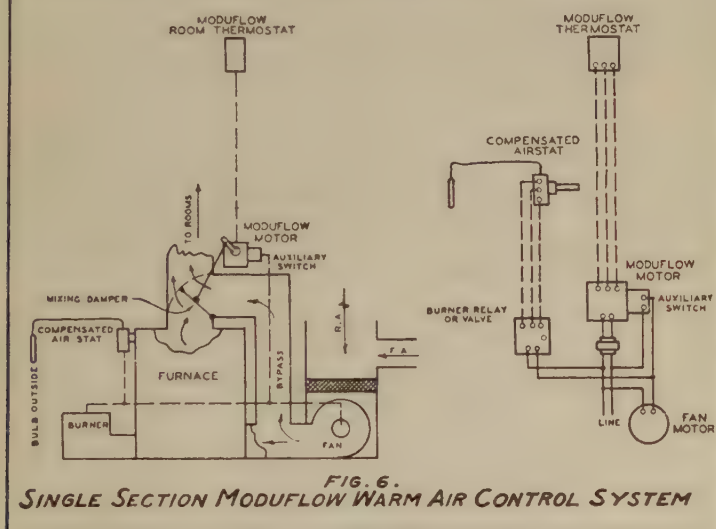


FIG. 6.
SINGLE SECTION MODUFLOW WARM AIR CONTROL SYSTEM

Figs. 5 and 6

creases, and vice versa. The fan continues to run except when the by-pass is nearly open, at which time an auxiliary switch on the Moduflow damper motor breaks the circuit to the fan, and to the burner, since this position indicates that no heat is required. This switch may be adjusted to stop the fan when 90% of the air is by-passed and 10% passing through the furnace. In this way a certain minimum volume of air is always passing through the furnace to insure uniform bonnet temperature when the burner is operating.

The burner should be controlled by a compensated Airstat in the bonnet of the furnace. The outdoor temperature governs the setting of the Airstat with the outside bulb resetting the Airstat to provide different bonnet temperatures as the weather changes. As the outside temperature decreases, the setting of the Airstat is automatically increased to provide a higher temperature in the bonnet. This allows the system to operate with a low bonnet temperature in mild weather, and the bonnet temperature increases as the outside temperature decreases, up to the maximum design temperature for extremely cold weather. The compensated Airstat prevents excessive heat loss from the furnace and casing during mild weather, and improves the overall efficiency of the furnace. A conventional Airstat may be used in place of the compensated Airstat if desired, in which case the bonnet will be maintained at the same temperature, regardless of outside temperature.

If the burner is of the modulating type, it will maintain a uniform temperature in the bonnet as called for by the compensating Airstat. If the burner is of the on-off type, the furnace will operate intermittently on full flame but with reduced air volume through the bonnet, and the furnace used must operate satisfactorily under these conditions. Some storage means should be provided so that the burner will not operate with objectionable frequency.

On some types of burners and furnaces, it may be necessary to provide a fan overrun control to start the fan in case of excessive temperatures in the bonnet, after the burner and fan have been shut off by the auxiliary switch, on the damper motor.

It is recommended that a dampered connection be made from the outside to the return air duct near the fan inlet, to supply a percentage of outdoor air to the system at all times. The damper should be adjusted to supply approximately the quantity of air which would normally leak into the building, and will vary for the average residence between one-half and one air changes an hour. The supply of this air at the furnace allows it to be heated to the temperature required, and will prevent drafts usually ex-

perienced near windows, doors and outside walls, since a slight pressure will be built up in the home preventing infiltration. This also tends to prevent dirt and dust from entering the home through windows, etc. An added refinement would be the use of a spring return damper motor operating the outdoor air damper so that the outdoor air damper will be closed except when the fan is running. This would prevent cold air entering the system in the basement during the night shutdown periods when no heat is being supplied.

Some types of high side wall or ceiling air outlets are more satisfactory than baseboard or floor outlets, since a lower outlet temperature may be used without causing objectionable drafts. For the same reason, carefully selected diffusion type grills should be used to insure draft-free installations. It is essential that the duct system and register locations be carefully designed to produce the most satisfactory installation.

Sectionalized control may be obtained by the use of multiple furnace installations or with the by-pass system using one central furnace. Fig. 7, shows a central furnace by-pass system with two sections. Additional sections may be added if desired. For the two or more sectionalized system, the same burner and furnace controls are required. The only additional equipment required is a Moduflow thermostat and damper motor for each section. Each of the damper motors is equipped with an auxiliary switch. The auxiliary switches are wired parallel, so that the fan and burner are cut off when all sections are satisfied, (by-pass open).

For any of the warm air systems described, a clock or Da-Nite thermostat may be used to provide night shutdown. Where sectionalized control is used, each section may be controlled independently. With this type of installation the auxiliary switches on the damper motors break the circuit to the fan and burner for night operation, until the temperature drops below the setting of one of the night thermostats. If this occurs, the circuit is made, starting both the fan and the burner as the mixing dampers to the home or sections start to open and allow heating. As soon as the clock thermostats call for day operation, they will control at their daytime temperature setting.

Some existing forced warm air systems may be converted to Moduflow control systems by installing by-passes between the blower and the furnace. In most cases, it will be necessary to change the basement duct to work to sectionalize an existing heating system. New homes should be carefully checked before construction is started, and the warm air ducts designed so that the desired number of sections may be installed.

Typical Specifications for Moduflow Control Systems

The following typical specifications are intended to assist architects and engineers. In using the typical specifications, it will usually be desirable to alter or expand them to meet individual requirements.

The specifications shown in parenthesis are alternates and their selection depends upon whether or not plain or clock thermostats are desired, etc.

Hot Water Heating Control Systems—Single Section

The automatic control system shall provide for the continuous flow of water to the radiators. The temperature of the water delivered to the radiators shall be changed automatically by means of a motorized three-way valve, mixing return and hot water to meet the heating requirements as determined by a modulating (clock) type thermostat located _____.

The water circulator shall run continuously except when the motorized three-way mixing valve has been positioned by the thermostat to close off the line from the boiler. At this point an auxiliary switch on the motorized valve shall shut off the water circulator.

An Aquastat on the boiler shall control the burner through the primary controls, (and the control point of the Aquastat shall be readjusted from outside temperatures automatically so that the water temperature will vary from _____ to _____ as the outside temperature varies from _____ to _____).

(If an indirect hot water heater is used, a constant temperature Aquastat should be used.)

Balancing cocks shall be installed in each return line.

Hot Water Heating Control Systems—Multiple Sections

The house shall be controlled in sections so that the _____, _____, and _____ (sleeping quarters, living quarters, service quarters, etc.) will be controlled separately.

The automatic control system shall provide for one continuous flow of water to the radiators. The temperature of the water delivered to the radiators shall be changed automatically by means of motorized three-way valves, mixing return and hot water to meet the heating requirements of each section as determined by a modulating (clock) type thermostat in each section, located _____.

The water circulator shall run continuously except when the motorized three-way mixing valves in all sections have been po-

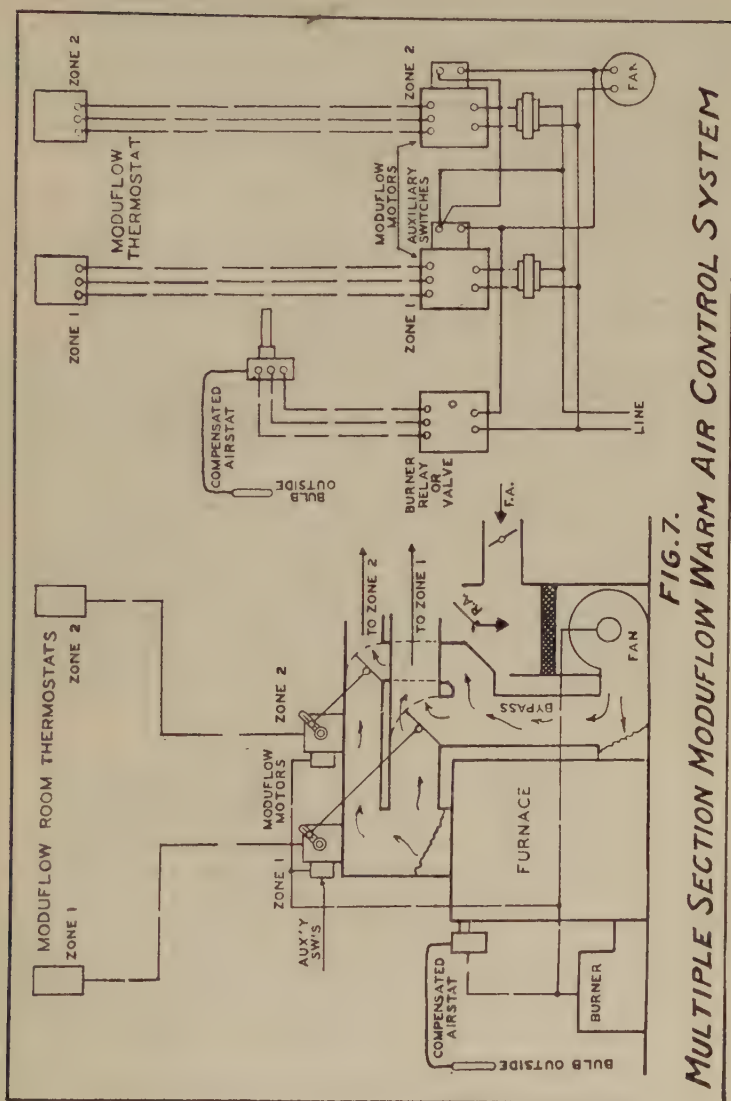


Fig. 7

sitioned by their corresponding thermostats to close off their lines from the boiler. At this point auxiliary switches on the automatic valve motors shall shut off the water circulator.

An Aquastat on the boiler shall control the burner through the primary controls (and the control point of the Aquastat shall be readjusted from outside temperatures automatically so that the water shall vary in temperature from _____ to _____ as the outside temperature varies from _____ to _____.)

(If an indirect hot water heater is used, a constant temperature Aquastat should be used.)

Balancing cocks shall be installed in each return line.

Steam Heating Control Systems—Single Section

The automatic control system shall provide for the continuous flow of steam to the radiators. The quantity of steam delivered shall be modulated automatically by means of a motorized three-way valve located in the main supply line to meet the heating requirements as determined by a modulating (clock) type thermostat located _____.

The steam pressure in the boiler shall be maintained at _____ pounds continuously by means of a Pressuretrol operating the burner through primary controls except when the motorized valve is closed. At this point an auxiliary switch on the automatic valve motor shall shut off the burner. Properly sized orifice plates shall be installed where the condensate cannot collect, when the valve is in its closed position. A positive means shall be provided to return the condensate to the boiler.

Steam Heating Control Systems—Multiple Sections

The house shall be controlled in sections so that the _____, _____, and _____, (sleeping quarters, living quarters, service quarters, etc.) will be controlled separately.

The automatic control system provides for a continuous flow of steam to the radiators. The quantity of steam delivered shall be modulated automatically by means of a motorized valve located in the main supply line to section to meet the heating requirements as determined by a modulating (clock) type thermostat in each section, located _____. The steam pressure in the boiler shall be maintained at _____ pounds continuously by means of a Pressuretrol operating the burner through primary controls, except when all of the motorized valves are closed. At this point switches on the automatic valve motors shall shut off the burner.

Properly sized orifice plates shall be installed at each radiator, to insure good steam distribution.

The steam valves shall be installed where condensate cannot collect when the valves are in their closed position. A positive means shall be provided to return the condensate to the boiler.

Warm Air Heating Control Systems—Single Section

The automatic control system shall provide for the continuous flow of air from the air outlets. The temperature of the air delivered from the air outlets shall be changed automatically by means of a motor operated damper, mixing return and heated air to meet the heating requirements as determined by a modulating (clock) type thermostat located _____.

The fan shall run continuously except when the motorized mixing damper has been positioned by the thermostat to close off the heater air connection. At this point an auxiliary switch on the automatic damper motor shall shut off the fan and the burner.

The air outlets shall be located seven feet from the floor on the inside wall of each room opposite the outside wall having the greatest exposure.

An Airstat on the bonnet of the furnace shall control the burner through the primary controls (and the control point of the Airstat shall be readjusted from outside temperatures automatically so that the bonnet temperature shall vary from _____ to _____ as the outside temperature varies from _____ to _____.)

Warm Air Heating Control Systems—Multiple Sections

The house shall be controlled in sections so that the _____, _____, and _____ (sleeping quarters, living quarters, service quarters, etc.) will be controlled separately.

The automatic control system shall provide for the continuous flow of air from the air outlets. The temperature of the air delivered from the air outlets shall be changed automatically by means of motor operated dampers, mixing return and heated air to meet the heating requirements of each section as determined by a modulating (clock) type thermostat in each section, located _____.

The fan shall run continuously except when the motorized mixing dampers in all sections have been positioned by their corresponding thermostats to close off their heated air connections. At this point auxiliary switches on the automatic damper motors shall shut off the fan and the burner.

The air outlets shall be located seven feet from the floor on the inside wall of each room opposite the outside wall having the greatest exposure. An Airstat on the bonnet of the furnace shall control the burner through the primary controls, (and the control point of the Airstat shall be readjusted from outside temperatures automatically so that the bonnet temperature will vary from _____ to _____ as the outside temperature varies from _____ to _____.)

CHAPTER XXXIV

THE HARTFORD LOOP

The purpose of the Hartford Loop in heating, is to prevent the water being backed out of the boiler under all possible conditions. It is a deep seal trap, used in connection with an equalizing pipe, and placed between that pipe and the main return.

The Hartford Loop represents an improvement in connecting up return lines in low pressure heating systems. The connection of the loop with the equalizer is best made just below the water line of the boiler. This plan helps to steady the water line and prevents entrance of steam into the return mains.

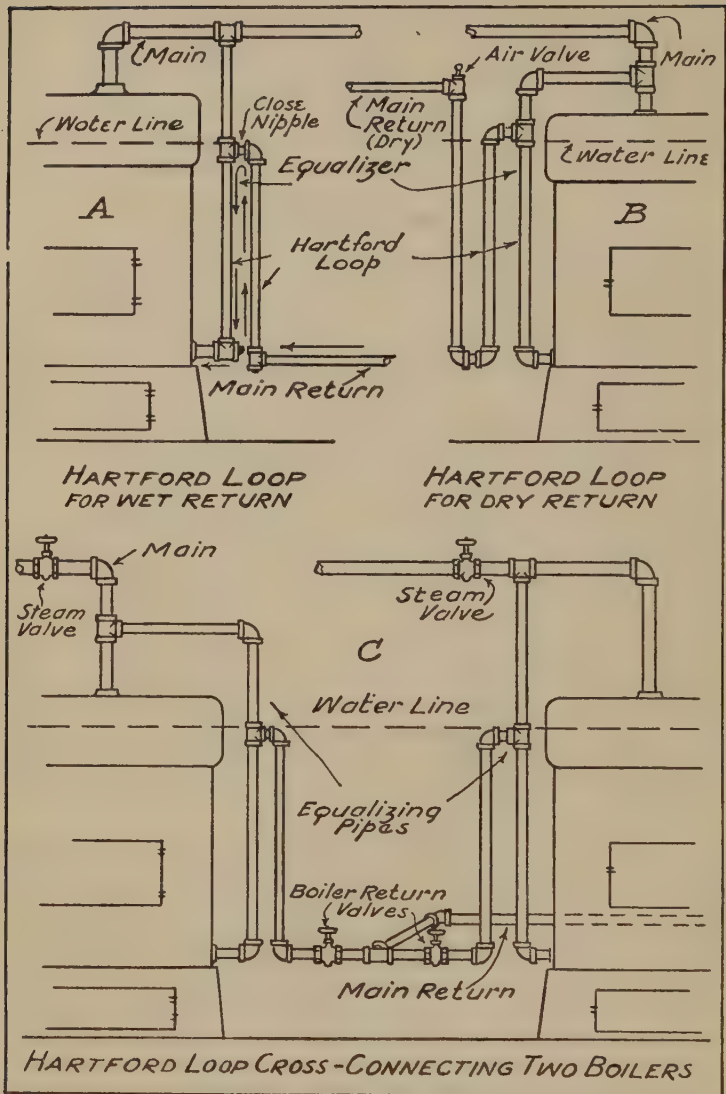
Use of a check valve on the return is not satisfactory. A small particle of grit or dirt of any kind drawing into the check valve and catching on the valve seat can easily prevent closing of the valve, thereby allowing boiler water to flow into the return.

The accompanying illustrations will clearly show the method of connecting the Hartford Loop. A and B show the loop connected to a single boiler, A showing a wet return and B a dry return. C shows two boilers cross connected, each boiler having its own loop. When the loop is connected as shown, it will maintain an equalized pressure on the top of the loop whenever there is steam pressure on the boiler.

In the case of the dry return (B), the return should be carried down to the return opening in the boiler, becoming a wet return.

In installing the Hartford loop, several important points should be observed. A valve should not be used between the boiler and the loop. The loop should be made up as close as possible, which necessitates using a close nipple as seen in A. The top of the loop should be slightly below the water line in the case of the wet return and slightly above it in the case of the dry return. When two boilers are cross connected, it should not be done with a single loop, but each boiler should have its own loop.

The equalizer or balance pipe, as it is also called, is a pipe connecting from the main steam line from the boiler to the top of the loop. Its purpose is to balance or equalize the pressures between the main and return pipes.



Hartford Loop

CHAPTER XXXV

THREE HUNDRED AND FIFTY EXAMINATION QUESTIONS

For the last fifty years plumber's examinations have been given by many of the states, and very generally in the cities, and larger towns of the country. This, however, has not been true of the heating trade. Within the last ten years, however, many of the steamfitters' unions have been giving heating examinations, and at the present time city examination boards are more and more falling into line.

We have never before published in either of our two books on heating, lists of examination questions as we have in our books on plumbing. We have now reached the conclusion that we should offer this same advantage to the steamfitter, and so we present the following list of three hundred and fifty questions.

The list should be separated into two sections, (1) questions answered in this book, (2) questions answered in "Modern Heating Illustrated."

Location of answers can generally be found by reference to the index. Many of the subjects covered by the questions are indexed under two headings. It will be noticed that quite a number of the questions involve simple operations in arithmetic. Inclusion of questions of this type is due principally to the fact that in recent years many examining boards apparently have reached the conclusion that in examining men for journeyman's or master's license, it is reasonable and fair that they should be expected to have the ability to use the simple rules which relate to problems commonly met in their daily work. We do not believe, however, that examiners should expect the applicants to answer complicated mathematical questions in such examinations, and we do not believe it is their intention to do so. Any textbook on arithmetic will give needed instruction for the answering of the questions here given.

Answers to the following list of questions will be found in this book.

1. Describe what a vacuum is.
2. Give the rule for finding the pressure per square inch of a column of water of any given height.

3. What is meant by the conduction of heat?
4. Name the different types of radiation in common use.
5. Describe a condensing tank.
6. What are the results of heating a piece of metal?
7. What happens when water is heated?
8. Of what materials are heating boilers made?
9. Does a cast iron or wrought iron boiler have the longer life?
10. Explain what a heat unit is.
11. How many cubic inches are there in a gallon of water?
12. What is the proper location of the safety valve on a heating system?
13. Explain what heat is.
14. In what ways is heat transferred from one body to another?
15. What pitch per foot should be used on the piping for a hot water heating system?
16. Show by simple pencil sketch what an equalizing pipe is.
17. Explain what is meant by the term "heating surface."
18. When and where is an expansion tank used?
19. Is an expansion tank used on a steam heating system? Why?
20. If there are 231 cubic in. in a gallon of water, how many gallons will 25 ft. of 3-in. pipe contain?
21. How many gallons of water are contained in a cylindrical tank 24-in. in diameter and 5-ft. long?
22. What is meant by radiation of heat?
23. What means of transmission of heat is mostly used in heating operations?
24. What two kinds of thermometers are mostly used for measuring degrees of heat?
25. Do you prefer hot water or steam heating? Give reasons.
26. How is heat measured?
27. Is an altitude gauge used on steam or hot water systems? What is its use?
28. What rule do you use for estimating radiation?
29. What is superheated steam?
30. Explain what the prime heating surface of a boiler is.
31. Why would it be wrong to use a valve on an expansion pipe?
32. Knowing the diameter and length of an expansion tank, how would you find its capacity in gallons?
33. Describe what is meant by grate surface.
34. Explain what the Fahrenheit temperature scale is.
35. When would you use pipe covering?
36. How does the covering of a boiler affect the size of the boiler to be used?
37. What is the B.T.U. or British Thermal Unit?

38. Give the rule for changing Fahrenheit temperature readings to Centigrade.
39. Give the rule for changing Centigrade readings to Fahrenheit temperature readings.
40. What is the boiling point of water?
41. What is a steam gauge used for? Where should it be connected?
42. What is an expansion tank used for?
43. Where is the overflow from an expansion tank discharged?
44. What is a condensing tank? Where located?
45. Make pencil sketch of a condensing tank and its connection.
46. What causes water hammer?
47. What is the advantage of a 45-degree pipe connection?
48. What is the Centigrade temperature scale?
49. Explain what is meant by indirect heating surface of a boiler.
50. Why is it required to locate an expansion tank where the temperature is moderate?
51. What is meant by atmospheric pressure?
52. How many pounds pressure is atmospheric pressure ordinarily considered to be?
53. How does heat and cold affect metals?
54. How does atmospheric pressure affect the boiling of water?
55. Explain how you would find the cubic contents of a rectangular tank, knowing its dimensions.
56. How does an altitude gauge work?
57. How large should an expansion tank be?
58. Expansion of water takes place differently than other liquids. Explain this.
59. Explain fluid friction.
60. What is saturated steam?
61. Describe the action of siphonage.
62. Is water more compressible than air?
63. Describe the process of evaporation.
64. What is the freezing point of water?
65. If a room is 15-ft. wide and 18-ft. long and 9-ft. high, what is the area of the four sides and the ceiling, no allowance being made for doors and windows?
66. A rectangular tank is 4-ft. wide, 8-ft. 6-in. long, and 24-in. deep. How many gallons does it hold? There are 231 cubic inches in a gallon.
67. How do you find the area of a rectangle? Of a triangle?
68. Why should not globe valves be used in heating systems?
69. How does a damper regulator work?
70. Explain what indirect radiation is.
71. Give the list of the various "trimmings" for a steam boiler.

72. What types of power boilers are in general use?
73. What qualities go to make up a good boiler?
74. Explain the meaning of latent heat.
75. At what pressure should a safety valve be set on low pressure heating?
76. Where should the steam gauge be located on a boiler?
77. What is the purpose of a water column and gauge?
78. How can the operation of a siphon be stopped?
79. How would you start a hard thread?
80. If two lines of 1-in. pipe are parallel and 2-ft. apart, what would be the length of the 45-degree offset between the two lines?
81. Name the different things you need to know in order to figure the radiation for a room.
82. How would you find the area of a circle?
83. Why is the use of gate valves advisable in heating?
84. Give a description of a sectional boiler.
85. What heat unit is generally used to measure heat?
86. How would you regulate a safety valve?
87. What does the steam gauge indicate?
88. How would you clean a gauge glass?
89. Explain how to adjust an altitude gauge?
90. What should be done when the water in a steam boiler is found to be very low?
91. What causes an unsteady water line in low pressure boilers?
92. How can an unsteady water line be overcome?
93. How is combustion effected by draft?
94. What factors cause good draft in a chimney flue?
95. How does the height of a chimney affect draft?
96. How many cubic inches in $3\frac{1}{4}$ gallons of water?
97. At what degree of temperature is water most dense, that is, at what temperature will it take up the least space?
98. Explain what pressure is as it is applied to a column of water.
99. What is meant by "head" as it applies to a column of water?
100. What is the area of a circle whose diameter is 2-ft. 3-in.?
101. What is the diameter of a circle whose area is 1562 sq. in.?
102. How much head does a column of water have, when the pressure of the water is 36-lbs. per sq. in.?
103. What is the best pressure at which to run a low pressure boiler?
104. Is a square or rectangular flue most satisfactory? Why?
105. Name causes of poor draft.
106. When the draft is too strong, what may happen?
107. How many gallons of water to the cubic foot?
108. How many gallons of water does 102-ft. of 2-in. pipe hold?

109. How many square inches in one square foot? In one square yard?
110. Combustion being a ¹¹⁰chemical action, on what does it depend?
111. Subtract 111.72 from 125.9/10.
112. Why is a tile-line flue more efficient than a flue having a rough surface?
113. How is the area of a chimney flue determined?
114. How many pounds of water in a gallon?
115. What is the head of a column of water 35-ft. high?
116. Reduce 73 degrees Fahrenheit to Centigrade reading.
117. Reduce 92 degrees Centigrade to Fahrenheit reading.
118. At what pitch would you run a steam main?
119. Explain what a wet return is.
120. Show by simple pencil sketch how you would run a two-pipe steam job.
121. Explain the meaning of low pressure steam.
122. How would you estimate the radiation of a given room?
123. Name some of the features for an efficient chimney.
124. How many pounds does a cubic foot of water weigh?
125. How many gallons of water will a tank contain whose inside measurements are 8-ft. x $3\frac{1}{2}$ -ft. x 2-ft. deep?
126. How many cubic inches in one cubic foot?
127. Divide 152.75 by $9\frac{2}{3}$.
128. At what temperature should water leave a hot water boiler, and at what temperature should it return?
129. If the draft is too strong, how can the condition be overcome?
130. How many pounds are there in 30 gallons of water?
131. How many gallons of water will a cylindrical tank hold, which is 2-ft. in diameter and 6-ft. 2-in. long?
132. Multiply .007 by .92 by 70.63.
133. Why is combustion best in cold weather?
134. How is combustion measured?
135. Explain what a dry return is.
136. In the case of a circuit system of hot water heating, how should the air be relieved?
137. What is the proper way to make steam radiation connections? Use pencil sketch, if desired.
138. Make a pencil sketch of an overhead steam heating system.
139. What is the minimum size of chimney flue that should be used?
140. What is the pressure per square inch on the bottom of a tank that is 8-ft. 6-in. deep, and full of water?
141. What is the reason for using air valves on a heating system?

142. On a hot water system are the mains pitched up or down from the boiler? Why?
143. Does hot air tend to fall or rise, and how is this fact used in heating operations?
144. Is it right or wrong to use a tee 'bullheaded' on a heating job? Why?
145. What are the advantages of the gate valve?
146. Explain the meaning of the word "combustion."
147. Why is hard coal mostly used in house heating?
148. Is it advisable to use the largest or the smallest sizes of coal possible?
149. On steam jobs what is the best type of valve to use?
150. Why is it poor practice to use globe valves on the heating system?
151. Give a brief general description of an exhaust heating system.
152. Describe a vacuum heating system. Use pencil sketch if desired.
153. Make a pencil sketch of the connections for two hot water boilers standing adjacent to each other.
154. Name several grades of anthracite coal.
155. Where would you locate the valves on a hot water system?
156. Show connections for heating a radiator located below the top of the boiler on the hot water system.
157. On steam jobs how is the matter of expansion on the piping taken care of?
158. Describe the two-pipe hot water heating system. Use pencil sketch if desired.
159. What is the cause of the water leaving a steam boiler and rushing up into the radiators?
160. How should a hot water system be filled?
161. On a hot water job what type of valve is best?
162. Explain what a drop riser is.
163. In an overhead hot water system, is it correct practice to use air vents on the radiators? Why?
164. What are the several grades of coal used for heating?
165. What is the right pitch for branch lines in hot water heating?
166. Normally the radiator on an upper floor gets more heat than on the first floor. What can be done to make this distribution of heat more even?
167. Show connections for an overhead system of hot water heating.
168. Name three low pressure heating systems.
169. How are radiator connections made in overhead hot water systems?

170. In heating, what is the meaning of high pressure steam?
171. Describe a swing joint.
172. What is an open system of hot water heating?
173. What is a closed system of hot water heating?
174. How should first floor radiator branches be connected in steam heating?
175. Show connections between a tank heater and hot water storage tank.
176. Show by pencil sketch, a one-pipe steam heating system.
177. What are the common sizes of bituminous coal?
178. What is exposed wall surface?
179. How many valves are used on a hot water radiator?
180. In an overhead steam heating system, how would you make the radiator connections? Use pencil sketch if desired.
181. In a circuit hot water heating system where is the expansion tank connected?
182. Make a pencil sketch of connections for heating a storage tank by indirect heating.
183. Where should the highest point come on the main of a circuit system of hot water heating?
184. Explain how hot water circulates.
185. When a steam main is carried over a beam, what is done to take care of the condensation?
186. How should the expansion tank connections be made in an overhead heating system?
187. When could a check valve be used in heating?
188. Show by pencil sketch, riser connections to upper floors from a riser supplying radiation on the second floor.
189. Explain the general idea of the system of heating by forced circulation.
190. By pencil sketch show a hot water boiler using forced circulation.
191. In hot water heating are upper or lower floors the easier to heat? Why?
192. In forced circulation what sizes would flow connections be to various sizes of radiators?
193. By pencil sketch show the connections for the expansion tank in a forced circulation job.
194. Is forced circulation used on steam or hot water heating systems?
195. Describe or make a pencil sketch of a divided circuit steam system.
196. What is done to take care of the expansion of the hot water in a hot water heating system?
197. How would you take a branch off a main in a steam heating system?

198. Show how a forced circulation heating system is protected against excessive pressure.
199. Where should the circulation pump be connected on a forced circulation job?
200. How does the flow control valve operate in forced circulation?
201. How has forced circulation benefited heating?
202. Why are swing joints used in heating?
203. Make pencil sketch showing two hot water radiators on the same floor supplied by the same riser.
204. Explain how forced circulation creates a stronger circulation.
205. Describe the construction and operation of a circulating pump used in forced circulation.
206. Is the main flow pipe of a one-pipe or two-pipe steam heating system the larger? Why?
207. Why is a 45-degree connection off the main flow line in a steam heating system better than a top connection?
208. What advantage has the overhead hot water heating system?
209. How is condensation taken care of in a heating system?
210. Make pencil sketch of connections to a condensing tank.
211. Can older heating systems have forced circulation?
212. Where is the flow control valve installed in a forced circulation job?
213. Does forced circulation increase cost of the heating system? Explain.
214. In what type of buildings is the circuit system of heating mostly used?
215. Explain the construction and operation of an indirect heater.
216. With what kind of heating system can the indirect heater be used?
217. What are the advantages of forced circulation over older systems of heating?
218. Explain what a flow control valve is.
219. Name advantages of the circuit system of heating.
220. What is an indirect heater?
221. Is it correct to install the circulation pump on the flow or the return?
222. Can an indirect heater be used in connection with the steam heater?
223. What is the smallest size of pipe that can be used in supplying radiation using forced circulation?
224. What other uses has the indirect heater besides supplying domestic hot water?
225. Name some of the advantages of forced circulation.

226. In a forced circulation system, how is the main flow line generally run?
 227. Explain why smaller pipe can be used in forced circulation than in any other system of heating?
 228. Do radiators and piping have to be changed in converting old-type heating systems to forced circulation?
 229. What is water composed of?
 230. Explain the fundamental difference between forced circulation and the older methods of heating.
 231. Can the indirect heater be used in connection with vapor heating boilers?
 232. Can forced circulation be used to advantage on large heating systems?
 233. Explain what evaporation is.
 234. Explain what a vacuum is.
 235. What is the composition of air?
 236. Explain the action of condensation.
 237. How is pipe covering put on?
 238. How do you make reductions in size of pipe?
 239. How is a vacuum produced on a heating job?
 240. What is meant by the natural ventilation of houses?
 241. What kinds of materials are used for pipe coverings?
 242. Describe the principle of circulation.
 243. Is the friction of water greater in large or small pipes? Why?
 244. Why must mechanized means be used in providing ventilation for such buildings as schools?
 245. Where should radiators generally be located?
 246. What is prime radiating surface?
 247. What is indirect radiation?
 248. What are some of the advantages and disadvantages of indirect radiation?
 249. What three kinds of radiation are in common use?
 250. What is the result when a radiator becomes air bound?
- Answers to the following questions may be found in "Modern Heating Illustrated" which is a companion book to this one.
251. What is the definition of B.T.U.?
 252. Show connections for heating basement radiators in forced circulation.
 253. Show connections for radiators on same floor as boiler, under forced circulation.
 254. How can forced circulation be applied to summer-winter heating?
 255. What are the proper requirements for selecting an indirect water heater?
 256. Make sketch showing general features of a vapor heating system.

257. Describe flow control for vapor and vacuum heating systems.
258. Explain what a steam trap is?
259. In selecting a steam trap what qualities should be expected in it?
260. Why is the removal of air important in a steam trap?
261. Why is "unit trapping" better than "group trapping"?
262. Explain zone control with forced circulation.
263. Make pencil sketch of a single-pipe vapor heating system.
264. Explain how an old type steam heating system can be converted to a vapor heating system.
265. Show by pencil sketch the principal feature of the two-pipe vapor heating system.
266. Where are steam traps used?
267. Can complete freedom from loss of steam be expected in a steam trap?
268. Explain what a combination float and thermostat trap is.
269. What is a three-valve steam trap?
270. Name several different uses of steam traps.
271. Name three types of steam traps.
272. On what type of work is the inverted bucket trap especially effective?
273. Describe or make pencil sketch of a ball float steam trap.
274. Name some of the important considerations in installing a steam trap.
275. If a steam trap fails to discharge condensate, what may be the cause?
276. Show by pencil sketch the use of steam traps.
277. What is a thermostatic trap?
278. Describe the operation of a steam trap.
279. Make pencil sketch of use of steam traps in drainage of condensation from an air storage tank.
280. Describe the construction and operation of an open bucket steam trap.
281. If a steam trap discharges water continually what may be the cause?
282. What is the method of dripping a steam main to a non-pressure wet return?
283. Show connections for a dirt strainer.
284. Show the construction and operation of an open bucket steam trap.
285. What is meant by condensate?
286. Show use of thermostatic trap in dripping the end of the supply main.
287. Make pencil sketch of use of steam trap in dripping high pressure steam main.
288. If a steam trap blows live steam, name some of the possible causes.

289. Describe the construction and operation of a vent trap.
290. What are some of the uses of thermostatic traps?
291. When a steam trap operates in a satisfactory manner, but units do not heat well, what may be the cause?
292. Describe the construction of a boiler return trap.
293. Show by pencil sketch, use of steam trap in drainage and venting of kettles.
294. Make pencil sketch of a heating pipe coil, with thermostatic trap.
295. Show use of float and thermostatic trap on unit heater.
296. Describe or make pencil sketch of safety relief valves connected to hot water heating boiler.
297. What is a water feeder?
298. What are some of the reasons for water disappearing from the gauge glass?
299. What is a Hartford connection?
300. Show by pencil sketch proper return connections to a single boiler without use of check valves.
301. What may cause too much water in the boiler?
302. Show thermostatic trap used on radiator.
303. Show thermostatic trap used on basement radiator below the dry return main.
304. What are some of the common errors in the installation of water feeders?
305. How would you test the feeder valves?
306. By pencil sketch show how to connect two boilers without use of check valves.
307. Make pencil sketch showing installation of a damper regulator.
308. What may be the cause of too much condensation being held up in the system?
309. Describe the process of cleaning heating systems.
310. What is a boiler protector?
311. Show connections for looping a dry return around a beam.
312. What is unit heating?
313. What is to be said concerning selection of traps for unit heaters?
314. Show piping connections for a unit heater on low pressure gravity steam systems.
315. Show piping connections, with trap, for a unit heater on a standard vacuum heating system.
316. Show method of locating unit heaters in a factory building.
317. Show connections for looping a steam main around a beam.
318. What is the method of connecting air lines to vacuum returns where returns cross under doorways?
319. Show piping connections for a unit heater on a high pressure heating system.

320. Explain operation of vapor disc thermostat.
321. Show piping connections for a unit heater drained to an overhead return.
322. What is the I-B-R installation guide No. 1?
323. Make pencil sketch of one-pipe steam heating system.
324. What is a diaphragm radiator valve?
325. Explain what zone control is.
326. When is zone control necessary?
327. Show how zone control can be applied to gravity circulation hot water systems.
328. Show how zone control can be applied to forced hot water heating systems.
329. Make pencil sketch of overhead system of steam heating.
330. Describe a heating system "controlled by the weather."
331. Make pencil sketch of hot water tank having temperature control.
332. Make pencil sketch of two-pipe system of steam heating.
333. What is the operation of a tempering valve?
334. Describe the operation of a circulation controller.
335. What is a water blender and how connected?
336. Make pencil sketch showing a circuit hot water heating system.
337. Describe a radiation heater, its use and connections.
338. What are the connections for a return line vacuum pump?
339. Describe principal features of a steam driven vacuum pump.
340. Make pencil sketch of an overhead system of hot water heating.
341. Show how zone control can be applied to steam heating systems.
342. Show connections for a condensator, and on what systems used.
343. Show how zone control can be applied to hot water heating systems.
344. Describe the method you prefer for estimating radiation.
345. What three things is the estimating of radiation based on?
346. Make a pencil sketch of a hot water heating system, in which boiler and radiator are on the same floor.
347. By taking some definite room, compare the amount of radiation required for it under the two methods given in the chapter in this book on estimating of radiation.
348. Figure the radiation for the same room as in question 347, using the I-B-R Installation Guide No. 1.
349. Give brief explanation of the I-B-R method of estimating radiation.
350. What is a steam flow meter, and its operation?

INDEX

A

- Accelerated (forced) hot water heating systems, 145.
- Benefits of, 146.
- Circulators for, 149.
- Flow control valve for, 149.
- Expansion tank for, 150.
- Pipe sizes for, 157.
- Air, composition of, 125.
- Compressibility of, 125.
- Heat contained in, 4.
- In dwellings, moving of, 92.
- In room, how changed, 91.
- Properties of, table, 5.
- Removed from heating system, 96.
- Required in combustion, 24.
- Required per person, 91.
- Vitiation of, 91.
- Volume, density and pressure of, table, 6.
- Air relief on circuit H. W. systems, 79.
- Air trap for Moline system, 96, 97.
- Air valve, for Trane system, 95, 96.
- On circuit system, 66.
- On main circuit line, 48.
- Purpose of, 47.
- Types of, 48.
- Air vents on overhead H. W. system, 82.
- Altitude gauge, action of, 15.
- Adjusting of, 15.
- Purpose of, 15.
- Angle, right, to prove, 134.
- Angles, table of, 137.
- Anthracoite coal, grades of, 26.
- Atmosphere, pressure of, 94.
- Atmospheric pressure, 123.
- Avoirdupois weight, table of, 136.

B

- Bishop-Babcock-Becker system, 96.
- Condenser for, 101.
- Bituminous coal, grades of, 26.
- Sizes of, 27.
- Boilers, cast iron, types of, 10.
- Cleaning of, 16.
- Covering of, 89, 90.
- Draft for, 17.
- Affect of shape of flue on, 19.
- Firing of, 25.
- For heating purposes, 7.
- For power purposes, 8.
- Heating capacity of, 12.
- Indirect heating surface of, 11.
- Prime heating surface of, 11.
- Rating of, 10.
- Requirements of, 11.
- Round, 10.
- Sectional, 10.
- To determine capacity of, 12.
- Boiler, low pressure, right pressure for, 15.
- Unsteady water lines in, 16.
- Boilers, steam, cleaning of, 15.
- Precautions with, 15.
- Boilers, tubular, capacity of, 10.
- Horsepower of, 9.
- Boiler scale, to remove, 131.
- Boiler tubes, measurement of, 50.
- Boiling point affected by atmospheric pressure, 123.
- Branches, pitch on, 58.
- Running of, 58.
- Supplied by hot water mains, 75.
- Brass, to clean, 131.
- Brick chimneys, requirements for, 22.
- British thermal unit, 2, 128.
- Broomell vapor system, 103.
- Devices for, 102.
- Buoyancy, 124.

C

- Cast iron, rusting of, 7.
- Cast iron boilers, types of, 10.
- Cast iron fittings, 51.
- Cast iron heaters, life of, 7.
- Cement for iron and stone, 131.
 - For leaky boilers, 131.
 - For steam boilers, 131.
 - Strong, to make, 130.
- Centigrade scale, 2.
- Centigrade readings converted to Fahrenheit, 3.
- Check valves, on two-pipe steam system, 71.
 - Use of, 48.
 - Used on one-pipe system, 64.
- Chimneys, brick, requirements for, 22.
 - Having two flues, 20.
 - Height of to secure draft, 17.
 - Location of, 23.
 - Purpose of, 17.
 - To increase draft of, 19.
- Chimney flues, 17.
 - Area of, 21.
 - Table of, 22.
- Chimney flue sizes for hot water, 21.
 - For steam, 20.
- Circles, to figure, 133.
- Circuit system of hot water heating, 79.
 - Combination fittings on, 80.
 - Sizes of mains, table, 79.
- Circuit system of steam heating, 56, 65.
 - Air valves on, 66.
 - Branches on, 66.
 - Divided, 65.
 - Mains on, 66.
 - Used in certain buildings, 65.
- Circulation, principle of, 124, 125.
- Clearance for pipe in refrigeration, 120.
- Closed tank systems of heating, 73.
- Coal, consumption of, 24.
 - Data on, 129.
 - Used in heating, 25, 26.

- Coal, anthracite, grades of, 26.
- Coal, bituminous, grades of, 26.
 - Sizes of, 27.
- Coal, semi-anthracite, grades of, 26.
- Coils, advantage of, 37.
 - Connections for, 38.
 - Extra boiler power in use of, 37.
 - To make, 130.
- Combination fittings, 80.
- Combustion, 24.
 - Air required for, 24.
 - Calculation of, 24.
 - Effect of draft on, 17.
- Compressibility of air and water, 125.
- Compressor, purpose of, 113.
- Condensation, 124.
 - Action of, 3.
- Condenser, action and construction, 113.
 - Double-pipe, repairing of, 119.
 - For Bishop-Babcock-Becker system, 101.
- Condenser return bend, 122.
- Conduction of heat, 1.
- Contraction, action of, 123.
- Crooked thread, to cut, 130.
- Cubic measure, table of, 136.
- Cylinder of pump, to compute diameter of, 132.
- Cylindrical tank, to find capacity of, 133.

D

- Damper regulator, adjusting of, 14.
 - Operation of, 14.
- Density of air, table, 6.
- Direct heating surface of boilers, 11.
- Direct radiation, location of, 28.
- Direct-indirect radiation, 44.
 - To estimate, 44.
- Direct-indirect radiator, use of, 45.
 - Location of, 45.
- Divided circuit system of heating, 65.
- Draft, cause of poor, 19.
 - Effect of, 17.
 - Flue requirements for, 17.

H

Hartford loop, 177.

Heat, 1.

Conduction of, 1.

Contained in air, 4.

Effects of, 1.

Equalization of, 4.

Latent, 3.

Lost through windows, 33.

Measurement of, 2.

Mechanical equivalent of, 3.

Radiation of, 2.

Transference of, 1.

Heaters, life of, 7.

Heating, coal used in, 26.

Evaporation in, 24.

Use of coal in, 25.

Heating capacity of boilers, 12.

Heating control systems, "Monoflow,"
161.Heating surface of boilers, indirect,
11.

Prime, 11.

Heating system, exhaust, 61.

Hot water, 73.

Indirect, 39.

Relief, 61.

Steam, 55.

Heating value of fuels, 27.

Heat unit, 2, 128.

High pressure steam, 61.

Pressures used in, 61.

Minneapolis-Honeywell heating control systems, 161.

Horsepower of boilers, to determine,
9.

Hot water branches, 80.

How made, 75.

Pitch on, 74.

Hot water heating, 73.

Flow and returns in, 74.

Grate and heating surface for, 78.

Loss of heat in, 78.

Valves for, 46.

Hot water heating systems, 73.

Accelerated, 105.

Circuit, 79.

Expansion tank on, 85.

Filling of, 77.

Overhead, 76, 81.

Pressure on, 105.

Regular, 83.

Two-pipe, 84.

Hot water mains, branches supplied
by, 75.

Minimum size of, 75.

Pitch on, 74.

Reduction of, 75.

Size of, 74.

Table of sizes, 30.

Hot water radiators, tappings for,
77, 78.

Hot water returns, 80.

Hot water risers, precautions in running,
78.

Hydraulics, 132.

I

Indirect heating surface, 11.

Indirect H. W. heaters, 105.

Indirect heating system, 39.

Advantages of, 40.

Flue sizes for, 43.

Radiation required by, 41.

Registers for, 40.

Returns for, 40.

Indirect radiation, 39.

Table, 41, 42.

To estimate, 40.

Ventilation provided by, 92.

Indirect radiators, making of, 39.

Tappings for, 43.

Indirect stack, 41, 42.

Casing for, 39.

Cold air duct into, 39.

Flues for, 40.

Location of, 39.

Number of floors served by, 40.

Insulation in refrigeration, 120, 122.

Of piping, 88.

Iron, to remove rust from, 131.

J

Joint sealer used on refrigeration,
115.

K

- K. M. C. system, floating checks for, 97, 98.
- Retainer valve for, 96, 97.
- Kriebel system, 104.
- Devices for, 102.

L

- Latent heat, 3.
- Linear measure, table of, 136.
- Linings, flue, rating of, 19.
- Liquids, pressure of, laws governing, 124.
- Liquid measure, table of, 136.
- Litharge used on refrigeration, 115.
- Long ton table, 137.
- Low pressure boiler, right pressure for, 15.
- Unsteady water line in, 16.
- Low pressure gravity heating system, 55.
- Low pressure steam, 55.
- Low pressure steam heating systems, 60.

M

- Main circuit line, air valve on, 48.
- Mains, steam, branches from, 58.
- Marble, to remove grease from, 132.
- Melting points of metals, 129.
- Mercury heat economizer, 108.
- Mercury seal device for Trane system, 97, 98.
- Metals, melting points of, 129.
- Metric equivalents, 138.
- Metric system, 137.
- Milwaukee heat generator, 107.
- Moline system, air trap for, 96, 97.

N

- Nervous water lines, cause of, 16.

O

- One-pipe steam mains, table of sizes, 30.
- One-pipe system of steam heating, 63.
- Check valves on, 64.

- Radiators on, 64.
- Returns for, 64.
- Table of sizes of mains, 63, 68.
- Open tank systems of heating, 73.
- Overflow from expansion tank, 86.
- Overhead system of hot water heating, 76, 81.
- Advantages of, 82.
- Air vents on, 82.
- Circulation on, 82.
- Overhead system of steam heating, 67.
- Radiator connections for, 36.
- Radiators on, 67.

P

- Packless radiator valve, 95, 96.
- Pipe, measurement of, 50.
- Used in refrigeration, 117, 118.
- Pipe and fittings, 49.
- Pipes, friction in, 49.
- Increase in capacity of, 49.
- Radiating surface of, table, 29, 30.
- Reaming of, 49.
- Table of capacities, 51, 53, 54, 141.
- Table of expansion of, 52.
- Table of internal areas, 51.
- Table of weights, 52.
- To compute capacity of, 134.
- To reduce size of, 50.
- Pipe areas, equalizing table of, 52.
- Pipe covering, 88.
- In refrigeration, 120, 122.
- Table of materials for, 88.
- Pipe threads, table of proportions, 53, 54.
- Plaster of Paris, to prevent quick setting of, 132.
- Pockets in steam mains, 58.
- Pop safety valve, 8.
- Power boilers, 9.
- Pressure hot water heating system, 105.
- Pressure of air, table, 6.
- Of liquids, laws of, 124.
- Pressure of water, table, 139, 140.
- To compute, 134.
- Prime heating surface of boilers, 11.

- Prime radiating surface, 29.
 Public buildings, ventilation of, 92.
 Pump cylinder, to compute diameter of, 132.
- R
- Radiating surface, extended, 29.
 Kinds of, 29.
 Prime, 29.
 Table, 29, 30.
 Radiation, 28.
 Approximate method of estimating, 32.
 Carried by one horsepower, 29.
 Direct, location of, 28.
 For accelerated system, to estimate, 109.
 Information necessary to figure, 31.
 Location in halls, 28.
 Location in large rooms, 28.
 Method of figuring, 31, 32.
 Of heat, 2.
 On upper floors, 34.
 Preference given to, 35.
 Required on indirect system, 41.
 Types of, 28.
 Upon what dependent, 31.
 Radiation, direct-indirect, 44.
 To estimate, 44.
 Radiation, indirect, 39.
 Table of, 41, 42.
 To estimate, 40.
 Radiators, connections for, on overhead system, 36.
 Heated by hot water, 77.
 Hot water, tappings for, 77.
 On one-pipe steam system, 64.
 Result of air in, 47.
 Steam, valves for, 46.
 To compute surface of, 29.
 Types of, 28.
 Vapor supplied to, 101.
 Radiators, direct-indirect, location of, 45.
 Use of, 45.
 Radiators, indirect, 39.
 Radiator connections, 36.
 Expansion for, 37.
 * On two-pipe system, 36.
 Steam, 36.
 Radiator tappings, 31.
 Indirect, 43.
 Radiator trap for Dunham system, 95, 96.
 Radiator valves, packless, 95, 96.
 Setting of, 47.
 Steam, location of, 46.
 Rating of cast iron boilers, 10.
 Reaming of pipes, 49.
 Receiver, connections for, 114.
 Recipes, 130.
 Rectangle, to find area of, 133.
 Refrigeration, 113.
 Clearance for pipes, 120.
 Connections for, 116.
 Essentials of, 113.
 Fittings for, 117.
 Flanged joints in, 117, 118.
 Insulation in, 120, 122.
 Joint sealer used in, 115.
 Litharge used in, 115.
 Pipe used in, 117, 118.
 Piping for, 113.
 Pressures used in, 115.
 Process of, 114.
 Valves used in, 115, 117.
 Registers for indirect heating, 40.
 Relief heating system, 61.
 Retainer valve for K. M. C. system, 96, 97.
 Return, definition of, 57.
 Dry, 64.
 Returns for indirect heating, 40.
 For one-pipe steam system, 64.
 Risers, 57.
 Drips for, 62.
 Steam, running of, 58.
 Round boilers, 10.
 Rust, to remove from iron, 131.
 To remove from steel, 131.
 Rusting of cast iron, wrought iron and steel, 7.
 Rust joint, to make, 131.

S

- Safety valve, care of, 14.
 - Location of, 13.
 - On closed tank system, 73.
 - Pop, 8.
 - Regulation of, 13.
 - Use of, 13.
- Saturated steam, 4.
- Scale, removal of from boilers, 16.
- Sectional boiler, 10.
- Semi-anthracite coal, grades of, 26.
- Smoke pipe connections, 18.
- Square measure, table of, 136.
- Stack, indirect, 41, 42.
 - Casing for, 39.
 - Cold air duct into, 39.
 - Location of, 39.
 - Number of floors served by, 40.
- Steam, elastic force of, 126.
 - High pressure, 61.
 - Low pressure, 55.
 - Saturated, 4.
 - Superheated, 4.
 - Temperature of, table, 60.
- Steam and hot water heating compared, 55.
- Steam boilers, cause of water leaving, 16.
 - Cement for, 131.
 - Cleaning of, 15.
 - Precautions in use of, 15.
 - Trimming for, 13.
- Steam gauge for low pressure plants, 14.
 - Location of, 14.
 - Purpose of, 13.
- Steam heating apparatus, table of proportions for, 11.
- Steam heating, 55.
 - Circuit system of, 56, 65.
 - Systems used in, 55.
- Steam heating plant, testing of, 59.
- Steam heating system, high pressure, pressure used in, 61.
 - Low pressure, 55, 57, 60.
 - Minimum size of main, 57.
 - Minimum size of riser, 57.
 - One-pipe, 63.

- Overhead, 67.
- Two-pipe, 69.
 - Use of small pipes on, 57.
- Steam joints, to make tight, 131.
- Steam mains, 57.
 - Alignment of, 58.
 - Branches from, 58.
 - Carried above boiler, 57.
 - Drip pipes for, 62.
 - For one-pipe system, table, 63.
 - One-pipe, table of sizes, 30, 68.
 - Pockets in, 58.
 - Relative sizes of, 63.
- Steam piping, water hammer in, 59.
- Steam radiator connections, 36.
- Steam radiator valves, 46, 48.
 - Closing of, 46.
 - Location of, 46.
- Steel, rusting of, 7.
 - To remove rust from, 131.
- Steel heaters, life of, 7.
- Superheated steam, 4.
- Syphon, action of, 126.

T

- Tanks, capacity of, table, 141.
 - Cylindrical, to find capacity of, 133.
 - Rectangular, to find capacity of, 133.
- Tappings for hot water radiators, 77, 78.
 - Indirect radiator, table, 43.
 - Radiator, 31.
- Tees, reading of, 50.
- Temperature, equalization of, 4.
 - For heating residences, 59.
 - In hot water heating system, 78.
 - Of fire, table, 27.
 - Of fusion, 3.
 - Of steam, table, 60.
 - Of vaporization, 3.
- Testing of piping in refrigeration, 117, 119.
 - Of steam heating plant, 59.
- Thread, crooked, to cut, 130.
 - Hard, to start, 130.
 - To cut smaller than standard, 130.

- Trane system, air valve for, 95, 96.
 Mercury seal for, 97, 98.
 Triangle, to find area of, 133.
 Trimmings for steam boilers, 13.
 Troy weight table, 137.
 Tubular boilers, capacity of, 10.
 Horsepower of, 9.
 Materials for bricking, 9.
 Two-pipe radiator connections, 36.
 Two-pipe system of H. W. heating, 84.
 Two-pipe system of steam heating, 69-72.
 Check valves on, 71.
 Table of mains and returns, 70.
- V
- Vacuum, 93, 124.
 Produced in heating system, 95.
 Vacuum heating, 93.
 Vacuum heating system, advantage of, 94, 95.
 Dependable, 104.
 Valves, 46.
 Air, purpose of, 47.
 Check, use of, 48.
 For hot water heating, 46, 48.
 For steam radiators, 46.
 Gate, advantage of, 47.
 Globe, objection to, 47, 48.
 Radiator, setting of, 47.
 Used in refrigeration, 115, 117.
 Used on expansion pipe, 86.
 Used on piping, 47.
 Used on steam systems, 63.
 Vapor heating, 93.
 Meaning of, 99.
 Vapor heating systems dependable, 104.
 Piping of, 101.
- Vaporization, meaning of, 3.
 * Temperature of, 3.
 Velocity of water, table of, 129.
 Ventilation, 91.
 Of houses, 91.
 Of public buildings, 92.
 Volume of air, table, 6.
- W
- Wall surface, exposed, 31.
 Water, absorption of heat by, 128.
 Boiling temperature of, 127.
 Composition of, 125.
 Compressibility of, 125.
 Expansion of, 123, 127.
 Friction of, 125.
 Power to raise, 134.
 Pressure of, 127.
 Table of discharge of, 143.
 Table of pressures of, 139, 140.
 Table of weights of, 142.
 To compute head of, 133.
 To compute lateral pressure of, 134.
 To compute pressure of, 133.
 Weight of, 127.
 Water column and gauge, 8.
 Purpose of, 14.
 Water hammer in steam pipes, 59.
 Water lines, nervous, cause of, 16.
 Water line of boiler, radiators located near, 59.
 Windows, heat loss from, 33.
 Table of glass in, 33.
 Wrought iron, rusting of, 7.
 Wrought iron heaters, life of, 7.
- Y
- Y's, reading of, 50.

PUBLICATIONS ON STEAM AND HOT WATER HEATING

By R. M. STARBUCK

"Questions and Answers on the Practice and Theory of Steam and Hot Water Heating"

172 Pages 6 x 9 in.—75 Illustrations

Nationally Known as

**STARBUCK'S
GREY BOOK**

Price—\$3.00 Postpaid

Special Offer: The Grey Book and Plumber's Library combined, \$13.50 Postpaid

"MODERN HEATING ILLUSTRATED"

260 Pages—6 in. x 9 in.

"MODERN HEATING ILLUSTRATED"

Takes up

WHERE THE "GREY BOOK" LEAVES OFF

155 FULL-PAGE ILLUSTRATIONS
with many others scattered through the text

A TOTAL OF

362 SEPARATE ILLUSTRATIONS

Price—\$3.50—Postpaid

R. M. STARBUCK & SONS, Incorporated
P. O. BOX 1318 **HARTFORD, CONN.**

"MATHEMATICS FOR THE PLUMBER AND FITTER"

PUBLISHED MARCH, 1947

Latest Book in the Starbuck Line of Publications for the
PLUMBING AND HEATING TRADES

The incentive for publishing this book just at this time is the great need of such a text-book for the vast number of ex-service men now being trained to take their places in the plumbing and heating industries.

THE BOOK COVERS

a wide range of practical subjects relating to
plumbing and heating.

COMMERCIAL MATHEMATICS

Fundamentals of Mathematics including fractions, decimals, ratio and proportion, square and cube root, etc., etc.

Complete Instructions in the use of
SLIDE RULE

MANY PRACTICAL RULES, TABLES, ETC., ETC.

180 Pages — 6 x 9 Ins.

Price \$3.00 Postpaid

R. M. STARBUCK & SONS, INC.

P. O. Box 1318, Hartford, Conn.

“PLUMBING INSTALLATIONS”

VOLUME I

THE LATEST STARBUCK PUBLICATION

275 PAGES — 6 x 9 in.

CHIEF FEATURE OF THIS BOOK

**is its many full-page illustrations, showing
elevations of Modern Plumbing Installations**

180 FULL-PAGE ILLUSTRATIONS

310 SEPARATE ILLUSTRATIONS

PARTIAL CONTENTS:—Plumbing Elevations for All Types of Dwellings, for Single and Double Batteries of Fixtures—Elevations Showing Plumbing Installed according to Plumbing Codes of 25 Largest Cities and 7 States—Installation of Kitchen Fixtures for Hotels, Restaurants and Clubs—Plumbing for Tourist Camps—Flood Control—Special Modern Venting—Hydraulic Gradient—Garages—Servicing of Modern Flush Valves—Modern Pneumatic Sewage Disposal—Sump and Sewage Pumps—Large Drainage Problems—Modern Grease Interceptors—Automatic Fire Sprinkler Systems—Fundamentals of Refrigeration—Hot and Cold Supply for Skyscrapers—Cooling Systems for Drinking Water, Etc., Etc.

Price Postpaid \$3.50

R. M. STARBUCK & SONS, Incorporated

P. O. BOX 1318

HARTFORD, CONN.

"DRAWING AND BLUE PRINT READING FOR THE PLUMBER & FITTER"

Published September, 1948

160 Pages — 6 in. x 9 in.

90 Full Page Illustrations

Total of 185 Separate Illustrations

A COMPLETE COMPREHENSIVE TEXT BOOK

PARTIAL LIST OF CHAPTERS

Drawing Tools and Equipment and Use of—First Steps Leading to Blue Print Reading—Fundamentals of Mechanical Drawing—Projection—Practice Exercises—Projection Applied to Piping—Best Method of Drawing Pipe and Fittings—Sectional Views—Dimensioning—Scale Drawings—Isometric and Mechanical Perspective Drawing—Inking and Shading.

Price — \$3.00 Postpaid

R. M. STARBUCK & SONS, Incorporated

P. O. Box 1318

Hartford 1, Conn.

PUBLICATIONS ON PLUMBING

By R. M. STARBUCK

THE PLUMBER'S LIBRARY

Four Volumes Entitled

"QUESTIONS AND ANSWERS ON THE PRACTICE AND THEORY OF SANITARY PLUMBING"

These books are 6 in. x 9 in. As a connected series, they
cover the entire field of plumbing

These books are popularly known as the
STARBUCK RED, BLUE, GREEN AND BROWN BOOKS

The Plumber's Library Gives a Complete Preparation FOR ALL PLUMBING EXAMINATIONS

Each book contains a long list of Examination Questions, the
total number being 1500.

Each Book Profusely Illustrated

THE RED BOOK—Vol. I

Drainage and Venting \$3.00

THE BLUE BOOK—Vol. II

Domestic Hot Water Supply and Circulation \$3.00

THE GREEN BOOK—Vol. III

Practical Subjects \$3.00

THE BROWN BOOK—Vol. IV

Drainage and Venting \$3.00

SPECIAL OFFER

THE RED, BLUE, GREEN AND BROWN BOOKS

4 Volumes—\$11.00 Postpaid

(Regular Price—\$12.00)

If GREY BOOK included—\$13.50 Postpaid

R. M. STARBUCK & SONS, Incorporated

P. O. BOX 1318

HARTFORD, CONN.

PUBLICATIONS ON PLUMBING

By R. M. STARBUCK

ESTIMATING FOR THE PLUMBING CONTRACTOR

175 Pages—6 in. x 9 in.—Profusely Illustrated

This book is comprehensive, concise, practical, clearly written and covers the needs of all classes of Plumbing Estimators.

For Beginners as Well as Experienced Estimators

Price—\$3.00 Postpaid

"PLUMBER'S EXAMINATION OUTFIT"

Most examinations now include the correcting of incorrect plumbing drawings known as Examination Charts. The Examination Outfit, consisting of 10 incorrect plumbing drawings, will enable the plumber to pass this kind of an examination. Study and correction of these drawings, makes a complete preparation.

Price—\$4.00 Postpaid

ISOMETRIC DRAWING FOR PLUMBERS AND FITTERS

FOUR PLATES

Giving Complete Instruction in Making Isometric Drawings

Price—\$1.00 Postpaid

SEVEN HOOVER CODE DRAWINGS

11 inches by 17 inches

Showing 48 Layouts of Plumbing for Dwellings Under the Hoover Code

Price—\$2.25 Postpaid

OIL BURNER SERVICE MANUAL

325 Pages—Chiefly Commercial and Industrial Burners

Price—\$3.50 Postpaid

R. M. STARBUCK & SONS, Incorporated

P. O. BOX 1318

HARTFORD, CONN.

